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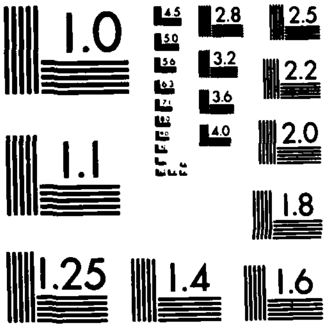

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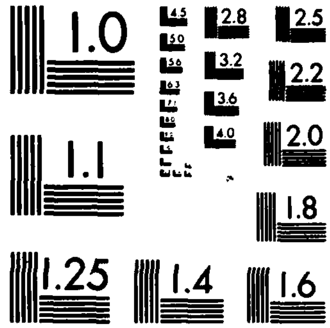

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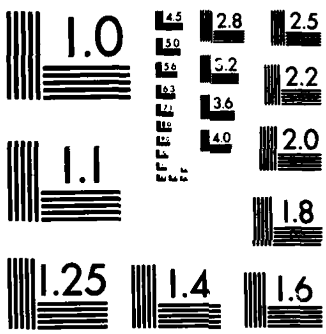

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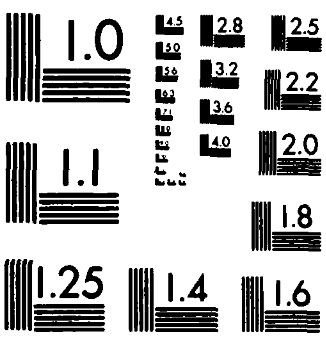

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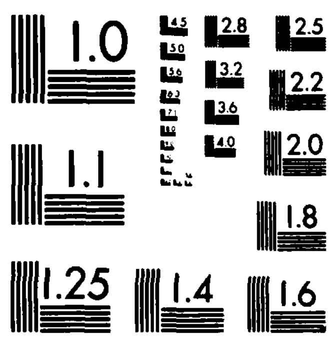

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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

MEASUREMENTS OF THE HORIZONTAL DIRECTIONALITY OF THE AMBIENT ACOUSTIC NOISE IN MONTEREY BAY, CALIFORNIA

by

Michael Joseph Gagliardi

March, 1982

Thesis Advisor: O. B. Wilson, Jr.

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Measurements of the Horizontal Directionality of the Ambient Acoustic Noise in Monterey Bay, California	5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March, 1982
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Michael Joseph Gagliardi	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	12. REPORT DATE March, 1982
	13. NUMBER OF PAGES 114
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Directionality, Ambient Noise Measurement

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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along the four cardinal directions and the frequency spectrum of the output was obtained. The frequency range of the system response was from 10 to 2500 Hz. Results are presented in the form of differences between the spectral energy bins in each direction and the average over all directions. Experimental difficulties with sonobuoy reliability prevented collection of extensive data. Some tentative conclusions are drawn from the results.

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Measurements of the Horizontal Directionality of the Ambient Acoustic Noise in Monterey Bay, California

by

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Lieutenant, United States Navy
B.A., University of Rochester, 1975

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

Measurements of some of the horizontal characteristics of acoustic ambient noise were carried out in the south-eastern parts of Monterey Bay, California, at a limited number of stations and for a limited number of ambient conditions. Directional hydrophones on buoys located at ranges of two to four miles from shore were used which have a steerable, cardioid-shaped pattern. The beam was successively aimed along the four cardinal directions and the frequency spectrum of the output was obtained. The frequency range of the system response was from 10 to 2500 Hz. Results are presented in the form of differences between the spectral energy bins in each direction and the average over all directions. Experimental difficulties with sonobuoy reliability prevented collection of extensive data. Some tentative conclusions are drawn from the results.

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ACKNOWLEDGMENT

I would like to express special thanks to Mr. Robert Smith, Mr. William Smith and Mr. Robert Moeller for ideas, encouragement, instrument construction and testing. I would also like to express gratitude to Mr. "Woody" Reynolds, the skipper of the RV Acania, and to his crew for their help in the placement and servicing of the sensors placed in the bay. This thesis was supported in part by the Naval Postgraduate School Research Foundation.

I. INTRODUCTION

The objective of this work was to sample the ambient acoustic noise in Monterey Bay and in particular to examine its horizontal directionality. Urick [Ref. 1] describes ambient noise as: "...may be said to be the noise of the sea itself." Urick expands this definition to state that "ambient noise truly surrounds the hydrophone on all sides, though unequally and in a nonisotropic manner." He explains further that for a given frequency in shallow water, the noise background is a mixture of three different types of noise: (a) shipping and industrial noise, (b) wind noise and (c) biological noise. At a particular time and place, the "mix" of these sources will determine the noise level, and because the mix varies with time, the existing noise levels will exhibit considerable variability from time to time and from place to place. He does not mention as a possible source the noise created by waves breaking on the beach.

The thesis was planned in the expectation of finding a preferred horizontal directionality to the ambient noise. A slightly modified version of the AN/SSQ53A Directional Lofar (DIFAR) sonobouy was used to listen to the ambient noise background. The DIFAR system provides a capability to form the cardioid shown in Figure 2-1. This cardioid can be

steered by the operator to listen in any direction relative to the earth's magnetic field.

Because of the variability of the ambient noise and limited battery life in the sonobuoys, the plan was to sample the ambient background noise over a period of time and varying weather conditions using a control clock in the buoy.

It was originally intended to have four listening stations at various distances from shore and at various depths along a West magnetic bearing from the beach at Fort Ord, California, on the eastern shore of Monterey Bay. They were to be placed at distances of approximately 1, 2, 4 and 8 miles off the beach. The water depth at each of these listening stations is 100, 200, 300 and 600 feet, respectively. Unfortunately, experimental difficulties resulted in data being collected at only two of these stations.

The anchoring systems were set in place by the RV Acania. On 16 April 1981, the following were set in place:

Station Number	Latitude North	Longitude West	Water Depth In Feet
1	36° 40.72'	121° 50.04'	116
2	36° 41.00'	121° 51.06'	195
3	36° 41.93'	121° 54.91'	290
4	36° 42.48'	121° 58.87'	570

All of these stations needed replacement due to loss and were replaced on 8 June as stated below.

Station Number	Latitude North	Longitude West	Water Depth In Feet
1	36° 40.69'	121° 50.31	110
2	36° 40.95	121° 51.16'	190
3	36° 41.91'	121° 54.93'	285
4	36° 42.47	121° 58.82'	585

One last effort at setting in anchoring systems was made in August. The placements were as follows:

Station Number	Latitude North	Longitude West	Water Depth In Feet
1	36° 40.91'	121° 51.61'	180
2	36° 42.75'	121° 58.51'	370

The servicing of the listening stations was accomplished by use of one of the following craft: (1) RV Acania; (2) Fort Ord range patrol craft; (3) 16 foot Boston Whaler or (4) 12 foot Zodiac.

The sonobuoys were controlled by an internal programmed clock which turned them on for approximately one-half hour about five times each twenty-four hour day. This was long enough for the operator to record the spectrum analysis of the output from the cardioid beam former with the major lobe of the beam oriented, successively, along the four cardinal directions (North, East, South and West) relative to the earth's magnetic pole.

The following pages describe the apparatus used, some of the experimental difficulties, methods of data analysis, and some typical data. Due to experimental difficulties, only

limited amounts of data were collected and analyzed. Although not a thorough study, this thesis presents one way of analyzing and presenting information about the horizontal directionality of ambient noise. Some tentative conclusions drawn from these results are presented.

II. EXPERIMENTAL APPARATUS

A. ACOUSTIC SENSORS

The sonobuoys were modified versions of Navy-furnished directional lofar (DIFAR) sonobuoys, model AN/SQQ-53A, which have been used by the US Navy as underwater acoustic sensors in its fleet air operations for a number of years. This buoy has a radio frequency transmitter for relaying the signals from a hydrophone package which consists of an omnidirectional hydrophone, two crossed, horizontally disposed pressure gradient or particle velocity sensors, a magnetic compass and a data transmission system which permits the operator of the receiving equipment to resolve separately the omnidirectional sound pressure and the North-South and East-West components of the sound wave. In addition, the operator may also, by adjusting the phase shift in one of the sub-carriers in the signal, steer one of the cosine receiving patterns from the horizontal magnetic field direction.

In these experiments, the rotatable cosine receiving pattern output was combined with the omnidirectional receiver output in a simple summing network so that the result, a cardioid receiving pattern, was developed which has a pattern function, ideally, of the following form:

$$H(\theta,\phi) = (1/2)(1 + \cos\theta\cos\phi)$$

where θ is the azimuthal angle and ϕ the elevation angle above the horizontal. The angle from which θ is measured could be rotated at will, as indicated above. A sketch of this receiving pattern, $H(\theta)$, is shown in Figure 2-1.

The directivity index for a cardioid pattern is not large (4.8dB) but the depth of the null has been measured in the ocean to be at least 15dB below that of the maximum lobe of the pattern using a source of simple harmonic waves. It was not possible to test the agreement between the theoretical and actual pattern shape.

The operating frequency range for these sonobuoys is from about 10Hz to about 2500Hz. Their response is not uniform, since a low frequency roll-off (at about -6dB per octave) in sensitivity below about one kHz is designed into the system.

Modifications were made to the sonobuoys in order to increase the battery capacity and to control the operating periods to permit sampling of noise data over a longer period of time. A new float package was constructed into which was placed the radio frequency transmitter from the sonobuoy, a rechargeable battery and a programmed clock which would turn the power on and off at selected times during a twenty-four hour period. A sketch of the arrangement in the float package is shown in Figure 2-2.

B. ANALYSIS EQUIPMENT

Signals were analyzed with the aid of a Hewlett-Packard 3825A spectrum analyzer. This device performs a 256 point sampling and Fast Fourier Transform. The control of the spectrum analyzer was provided by a Hewlett-Packard 9825 calculator and spectral data were plotted on an associated HP plotter. In most cases, the spectra presented are averages of 128 individual spectra, which represent an average over about one minute of signal sampling for the 0 to 2500 Hz band width case. A hanning window was used.

C. THE ENVIRONMENT AND SENSOR STATION GEOMETRY

The southeastern shore of Monterey Bay is relatively uniform or straight for a distance of 10 to 15 miles, being approximately parallel to the North-South magnetic direction. In the neighborhood of the beach at Fort Ord, California, the bathymetry is also relatively uniform along the perpendicular line out to a range of 12 nautical miles from shore where the depth is 100 fathoms. Beyond this, in the Monterey submarine canyon, the depth increases very rapidly and reaches 1000 fathoms within another two miles. A reproduction of a chart for this area is shown in Figure 2-3.

The beaches at Fort Ord are characterized by Bascom [Ref. 2] as steep. These beaches are exposed to the direct impact of swell from the northwesterly direction, which is the dominant arrival direction from distant storms. The

prevailing winds tend also to be from the westerly or northwesterly directions. The nature of the geometry of Monterey Bay also causes some focusing of the swell wave energy, so that the wave heights approaching the beach are about ten percent larger than those measured near the entrance to the Bay.

There were two anchoring systems used. The one used in the Spring (Figure 2-4) disappeared within a few days for reasons unknown. It is suspected that the systems were taken by passing boats or perhaps became caught in troll lines or fishing nets. It was replaced by the second setup shown in Figure 2-5. The anchor system in Figure 2-5 had a higher survival rate, which may be attributed to any of the following reasons: (1) The weight used was more massive which prevented it from being hauled aboard a vessel by hand; (2) While the stainless steel cable may have been of a higher monetary value, it was not as useful to the local fishermen as 3/8" polypropylene line; (3) there was no useful Danforth anchor; (4) the surface floats used on the second system were lower in the water, hence, less visible than the spar bouy of the first system.

There were problems in achieving adequate reliability of the hydrophone cable. The disposable DIFAR sonobouy system used by the Navy is depicted in Figure 2-6. This system is designed to work for up to four hours, and then is scuttled. The lower part of the sonobouy cable system (see Figure 2-6)

is designed to isolate the ver .ical motion of the surface float from the hydrophone package. The inertial unit consists of two plastic bags that fill with sea water and act as a mass. The spring unit is a length of flexible rubber tubing with two conductor wire wrapped in a cylindrical helix around it. The spring unit works in conjunction with the inertial unit as a motion isolator and damping unit. A plastic sheet section appears to be designed to damp transverse oscillation of the cable. Because the system is designed to operate for a short time and then be expended, mechanical components in the system do not hold together much longer than four hours.

Five different schemes were used to connect the upper package to the lower hydrophone units. All except one did not survive the punishment caused by the up and down motion of the surface unit due to the sea waves for any reasonable period of time. It was known from previous use of free floating DIFAR units that a likely cause of failure was breakage of the two conductor wire somewhere between the start of the inertial unit and the hydrophone package. From the onset, the strain on this length of two conductor wires was removed by running a slightly shorter length of 100 pound test monofilament fishing line in parallel with the power/signal wire through this section of the connecting cable. This solved the wire breakage problem in this section of the cable. Other places for problems to develop were in

the spring unit and in the wire connecting the spring unit to the watertight electrical connection on the surface unit. (see Figure 2-7)

The cable used in Model 1 was simply the connecting wire and vibration oscillator unit taken from a production DIFAR sonobouy and soldered to the watertight connector at one end and a modified (as mentioned earlier) inertial package. The weak points here were the flexible solid rubber tube and the thin two conductor wire.

Model 2 was supposed to overcome the weakness of Model 1 by substitution of heavier materials. In the DIFAR sonobouy system, there are two types of two conductor wire, one of a thinner wire as used in Model 1 and one slightly thicker wire, which is only used if "deep" is chosen on the sonobouy depth selection. The Model 2 vibration isolator was constructed by wrapping 110 feet of the thicker two conductor wire in a cylindrical helix around a 3/8" diameter copper pipe. A heat gun was used to set the wire in this spring-like configuration. A 15 foot length of surgical rubber tubing was passed through the copper pipe and secured to the wire at one end. The copper pipe was then removed and the surgical rubber tubing secured at the other end also. In order to strengthen the section between the surface float and the vibration isolator, 100 pound test monofilament nylon fishing line was connected in parallel with the electrical lead. The two conductor wire was secured to the monofilament

line about every 6 feet by a dab of RTV silicone rubber compound. All sections of the Model 2 connecting cable when soldered together formed what is referred to as a "spliced cable" elsewhere in the thesis. Model 2 had similar weak points as Model 1: (1) Electrical breaks still occurred in the wire between the surface and the isolator. (2) The surgical rubber tubing was stretched to the breaking point or to the point where it lost most of its resiliency.

Model 3 was built with the hope of correcting the problems encountered in Model 2. Neoprene coated three conductor cable was used to connect the isolator to the surface. A new isolator was made using a 15 foot length of surgical rubber tubing having thicker walls. Drip loops replaced the wound wire arrangement. The weak point was found to be the surgical rubber tubing.

Model 4 was exactly like Model 3 except that the resilient member of the vibration isolator was now a cloth covered rubber bungie taken from an older sonobuoy. The weak point was once again the compliant member in the isolator.

Model 5 was exactly like Model 3 except for the isolator. The isolator was made exactly like that in Model 2 with the exception that 6 mm diameter cloth-coated bungie cord was used instead of surgical rubber tubing. Although Model 5 is a workable alternative, it still has its weak points. The cylindrical helix made from the thicker two conductor wire does not stretch evenly throughout its entire length. Since

more of the stretch is absorbed by the upper part of the spring, this extra strain will probably eventually break the wire after enough time has passed.

There were two connecting cables made like Model 5. They are referred to in the thesis as the long and short connecting cables. They were identical except for the length of the neoprene coated three conductor wire. For the longer one, the overall length was 200 feet. The length was 100 feet for the shorter one.

III. CALIBRATION OF THE OMNIDIRECTIONAL HYDROPHONE

In order to correct for system response, it is necessary to determine the overall system sensitivity from the acoustic pressure to the receiver output. This calibration was carried out only for the omnidirectional hydrophone channel and was not attempted for the cardioid pattern. Urick [Ref. 1] and Bobber [Ref. 3] were consulted to obtain a workable calibration procedure. The procedures settled upon were the modified comparison method and the comparison method. Bobber [Ref. 2] explains the similarities and differences of the two methods of calibration and describes how to compute the system sensitivity. Both methods call for the use of three transducers: A hydrophone of known sensitivity (reference hydrophone); the hydrophone to be calibrated (unknown hydrophone); and the sound source. The difference between the two methods is in the placement of the reference hydrophone and the unknown hydrophone with respect to each other and the sound source. The modified comparison method requires simultaneously immersing both the reference and unknown hydrophones into the medium and the same sound field. The comparison method requires that the sound field be measured by the reference hydrophone which is then removed from the sound field and the unknown hydrophone is placed in

the position vacated by the reference hydrophone for its measurement of the sound field.

When the sensitivity curves calculated from the comparison method were compared to the sensitivity curves calculated by the modified comparison method, there appeared to be no significant difference over the frequency range of the system (10 - 2500 Hz).

The acoustic field was provided by a J-11 projector, excited by a filtered random noise voltage in the Naval Postgraduate School anechoic tanks. The output from the sonobouy receiver (unknown hydrophone) or reference hydrophone was measured using the same HP spectrum analyzer employed in the ambient noise analysis.

Block diagrams of the equipment setups used are shown in figures 3-1, 3-2 and 3-3.

In order to obtain adequate signal to noise ratio in the comparisons, filtering of the drive to the projector was done which permits a greater drive level in the frequency band of interest for the calibration. Calibrations for bands 0-500 Hz and 0-2500 Hz were done in order to provide data over the same bands as those employed in the ambient noise analysis.

Over the course of several months of work with various buoys, difficulties, described elsewhere, led to losses of calibrated hydrophone packages and some use of hydrophone packages in recording ambient noise data, and their subsequent loss before calibration could be carried out. For

this reason, individual hydrophone calibration for all equipment used cannot be presented. Appendix A presents typical sensitivity curves. As a check of equipment and procedure, occasionally the H-56 which was used as the reference hydrophone would be used as the unknown hydrophone and the sonobouy system along with a previously computed sensitivity curve would be used as the reference hydrophone, and a sensitivity curve for the H-56 hydrophone would be computed.

It was noted that there is a significant but not large difference in sonobouy system sensitivity if different elements of the system are changed. The smallest difference is produced by changing the connecting cable between the hydrophone package and the transmitter package. The greatest difference is seen by changing the transmitter package with the difference caused by changing the hydrophone package falling in between. The differences appear to be largest in the frequencies below 1kHz, where the roll-off in response exists.

IV. ANALYSIS OF DATA AND DISCUSSION OF RESULTS

Data were taken with the major lobe of the cardioid beam oriented, in succession, along the four cardinal magnetic directions, North, South, East and West. While listening at each direction, two spectrum analyses were done, one for the frequency range 0 to 500 Hz, and one for the range 0 to 2500 Hz. Figures 4-1 through 4-4 are examples of the data taken and stored. Wind, wave and tide data were also stored along with the data. An example of the information stored is shown in Figure 4-5. The data taken can be divided into two categories by location and time. Data taken between 11 May and 16 June are referred to as "Spring" data. Those taken between 21 Aug and 17 Sep are referred to as "Fall" data. The physical locations of the sonobouys for these two time periods are shown on Figure 4-6. Additional information recorded only during the Fall time period is the omnidirectional sound pressure level. Examples of these data are shown in Figures 4-7 and 4-8. Due to equipment problems documented elsewhere, a data base large enough to allow meaningful correlation between like environmental conditions was not obtained. Two methods were devised to present and interpret the information obtained.

The first method uses the spectra obtained from each of the cardinal directions for a given time and frequency range to compute an average spectrum. The spectrum for each cardinal point consists of 256 bins with band widths of 3 Hz for the 0 to 500 Hz range and 15 Hz for the 0 to 2500 Hz range. (A Hanning window was used in the spectrum analysis.)

The average spectrum was computed by finding the average bin energy from the bin levels. Let N[I], S[I], E[I], W[I] be the bin levels in dB re 1 volt of the Ith bin for the North, South, East and West cardinal directions, respectively. First, bin energies,

$$10^{\left(\frac{N(I)}{10}\right)}, \quad 10^{\left(\frac{S(I)}{10}\right)}, \quad 10^{\left(\frac{E(I)}{10}\right)}, \quad 10^{\left(\frac{W(I)}{10}\right)}$$

are found. These are averaged by summing and dividing by the number of directions, usually four.

$$P(I) = \frac{1}{4}\left(10^{\frac{N(I)}{10}} + 10^{\frac{S(I)}{10}} + 10^{\frac{E(I)}{10}} + 10^{\frac{W(I)}{10}}\right)$$

The average bin level for the I bin (A[I]) is then found by calculating

$$A(I) = 10 \operatorname{Log}_{10} \; [P(I)]$$

This is done for each of the 256 bins. An example of a computed average spectrum and the four data spectra used to compute the average are shown in Figures 4-9 through 4-12.

Once the average spectra have been computed, the differences for each directional bin level and the level of the average bin energy for that frequency are found and

displayed graphically as shown in Figures 4-13 through 4-16. These differences are placed into three arbitrary categories based on magnitude and sign. For one category, an arbitrary choice was made to call insignificant a difference of less than two decibels. The other two categories of significant difference are those in which the difference is positive or negative, but equal to or greater than two decibels.

The difference between the actual bin level and the computed average bin level is displayed in Figures 4-13 through 4-16. For each complete set of data for one of the five daily runs, there are four graphs for each of the two frequency ranges. Since each graph has 256 bins, there are 2048 bins for each complete set of data or 10,240 bins for a full day of data. In order to accomodate such large data sets, a method of consolidation chosen was to divide the given frequency range into 10 frequency bands. The first nine bands contain 25 bins each and the last frequency band contains 31 bins, for a total of 256 bins.

The question to be answered by looking at each frequency band was "If the data in this frequency band can be characterized as being significantly different, is it higher or lower than the computed average?" A frequency band was characterized as being significantly different if the majority of the differences between the directional and the average bin levels lies either above +2dB or below -2dB. Graphs such as Figure 4-13 through 4-16 were designed to show

where the majority of the differences between the directional and the average bin level were for each frequency band. As an example, inspection of Figure 4-13 for the 0 to 2500 Hz band shows that five bins had differences between +2dB and -2dB, 16 bins had differences between -2dB and -4dB, two bins had differences between -4dB and -6dB, one with a difference between -6dB and -8dB, and one in which the difference is between -8dB and -10dB. Hence, this frequency band would be characterized as being significantly different because the majority of the differences between the directional and the average bin level are below -2dB.

By keeping account of how the frequency blocks were scored (+ for the majority of bins being above +2db, 0 for the majority of bins being between +2db and -2db, and - for the majority of bins being below -2db), this information is displayed according to the frequency range, the time of day, and the time of year the data were collected. This information for the spring in the 0 to 500 Hz range is displayed in tables 4-1 through 4-5 for the data taken at 0300, 0800, 1300, 1800 and 2300 hours, respectively. Table 4-6 was constructed by combining all the information in tables 4-1 through 4-5. Tables 4-7 through 4-12 are similar in information content and grouping as tables 4-1 through 4-6 except that the frequency range is 0 to 2500 Hz. The data taken in the fall were treated in the same manner and displayed in tables 4-13 through 4-24. Tables 4-25 through

4-29 were constructed by combining the data of Spring and Fall for each time of day for the 0 to 500 Hz range. A similar combination is made for the 0 to 2500 range and is displayed in tables 4-30 through 4-34. Tables 4-35 and 4-36 are for frequency ranges 0 to 500 Hz and 0 to 2500 Hz, respectively, and were constructed by using all information available without regard to time of day.

There are some deficiencies with this method of analysis. First, all data collected cannot be used. If the information for any direction is missing for a particular data collection slot, the average spectrum cannot be formed and the data for the other three directions cannot be used. The result of sparse data can be seen in table 4-1. For a given frequency block where the differences in level looking in one particular direction is described by one category of the three and where only three data points are available for comparison, little confidence can be had in the grouping of these three data points.

Inspection of the data taken during the 2300 run (table 4-17) makes apparent several features. When the difference of the actual bin level and the computed average bin level is placed in one of the three categories, the majority of the differences will fall between +2db and -2db regardless of the frequency range and the direction being looked at. As a result, table 4-17 shows that if a significant difference exists between the directional bin level data taken and the

computed average bin level, it will change depending upon the direction. East and north are more likely to be greater than the computed average if there is a significant difference. West and south would be expected to be less than the average computed level according to table 4-17.

A presentation of an overall view of the results is given by Tables 4-36 and 4-37 which contain the total combined information for the Spring and Fall periods for the 0 to 500 Hz and 0 to 2500 Hz ranges. From Table 4-36 (0 to 500 Hz range), it appears that, regardless of the direction chosen for the cardioid beam, most frequently there is no significant difference between the actual bin level and the computed average bin level. However, when there is a significant difference, when listening in the westerly or southerly direction, most frequently the levels are less in these directions than are the computed average ambient noise levels. The opposite is true for the northerly direction where, if a significant difference occurs, most frequently the level is larger than the computed average ambient noise level. According to table 4-36, if there is a significant difference below 150 Hz, more frequently the easterly directed bin levels are less than the computed ambient noise level. Above 150 Hz, when differences are significant, they seem to be evenly split between the positive and negative categories. These observations hold fairly well also when the same information is presented by the time of day in the

Spring or Fall time period. (Tables 4-1 through 4-5, 4-13 through 4-17)

Conclusions for the 0 to 2500 Hz range can be drawn in a similar manner. Table 4-35 shows that most frequently, there was no significant difference between the observed directional bin levels and the computed average bin levels. It is also apparent that when looking in a northerly direction, if a significant difference is present, levels for the northerly direction are more frequently above the computed average ambient noise level. The opposite is true for the southerly direction where, when there is a significant difference, the southerly looking ambient noise level is more frequently below the computed average ambient noise level. Behavior of the easterly and westerly directed beam differences is different below and above 750 Hz. Above 750 Hz, for the easterly direction when the levels are significantly different, they are more frequently less than the average. Below 750 Hz, a significant difference seems just as likely to be positive or negative. This is also true for the westerly looking direction above 750 Hz. For the westerly direction and below 750 Hz, when there is a significant difference, it is more frequently less than the average, or negative.

The second method of grouping the data is to take the difference between the bin levels with the beam aimed to the East and those when aimed to the West. The same method of

grouping the bins into frequency bands was used but the definition of a significant difference was changed to 2.5db. The computer was once again used to produce graphs such as Figures 4-17 and 4-18 to facilitate the forming of tables 4-37 through 4-42. Tables 4-37 through 4-39 are for the 0 to 500 Hz range. Table 4-37 is made from data taken in the Spring while table 4-38 is from Fall data and table 4-39 is a combination of tables 4-37 and 4-38. Tables 4-40 through 4-42 are for the 0 to 2500 Hz range. Table 4-40 is made from data taken in the Spring while table 4-41 is from Fall data.

The data taken for the 0 to 500 Hz range in the Spring (table 4-37) indicate that when the ambient noise in one direction is stronger than the other, westerly levels are more frequently larger than the easterly levels . The data taken for the Fall (table 4-38) indicate the opposite.

The data taken for the 0 to 2500 Hz range need to be split into ranges, below and above 750 Hz. The data for both the Spring and Fall above 750 Hz indicate that if the ambient noise in one direction is stronger than in the other, it is more likely that the westerly level is larger than the easterly. Below 750 Hz, when significant differences occur, they are more likely to be higher from the easterly directions.

As mentioned earlier, a larger data base would have allowed more meaningful correlation and possible insights

into the causes of variations in the directional noise levels found.

As it is, one can only speculate about possible explanations for these observed differences in directionality of the noise. One source is, of course, ship and boat traffic. Another is the distribution of wind and wave noise sources. It is clear from inspection of Figure 4-6 that the areas from which wind and wave generated noise might reach the sensors is significantly larger to the North and West from the hydrophone than to the East and South.

A very likely cause for the East-West differences, particularly at the lower frequences, is the noise generated by waves breaking at the beach as reported by Wilson, et al. [Ref. 4] Because of limited sampling and lack of good wave height observation during these tests, these results are only suggestive.

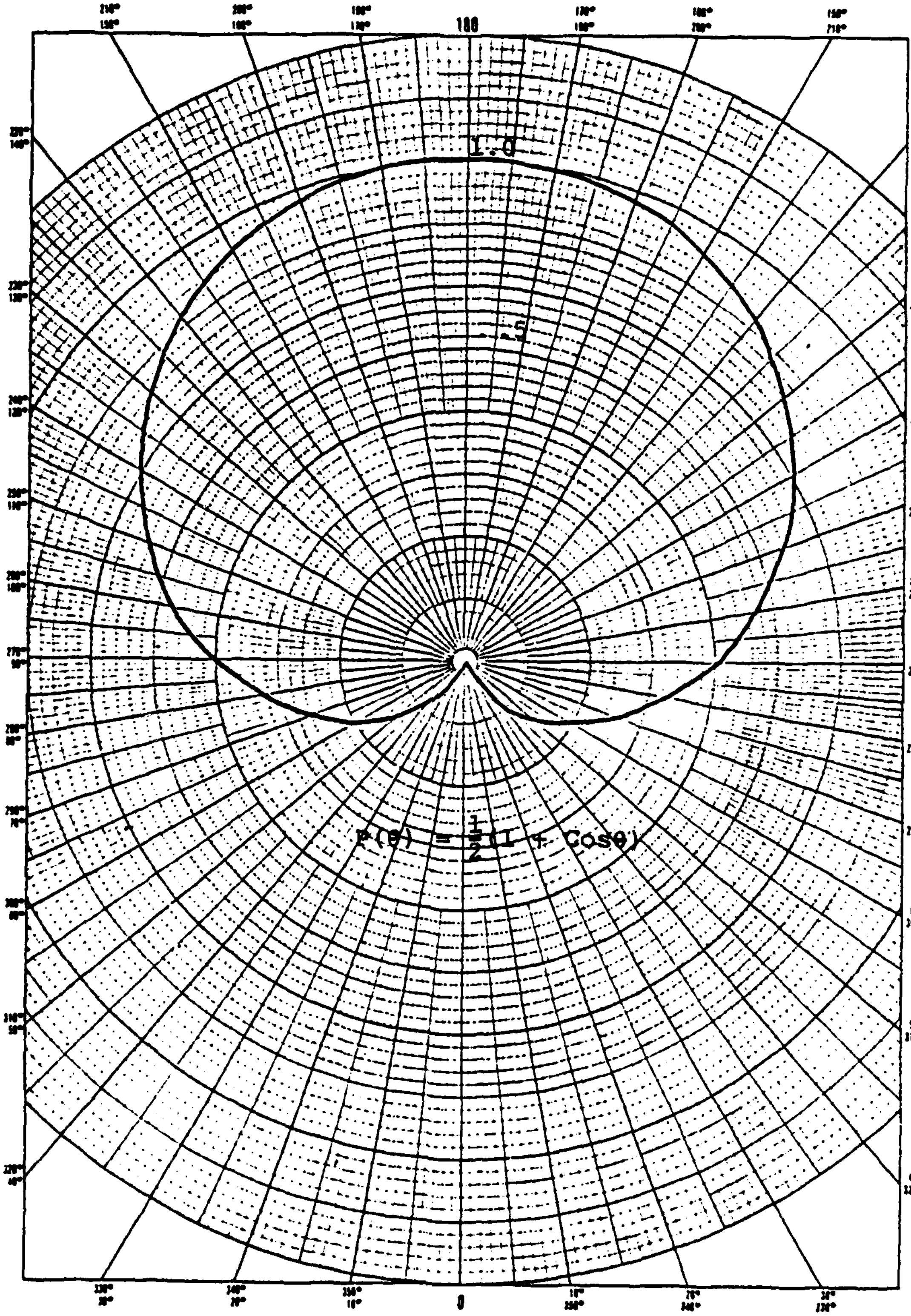

Figure 2-1: Cardioid Pattern

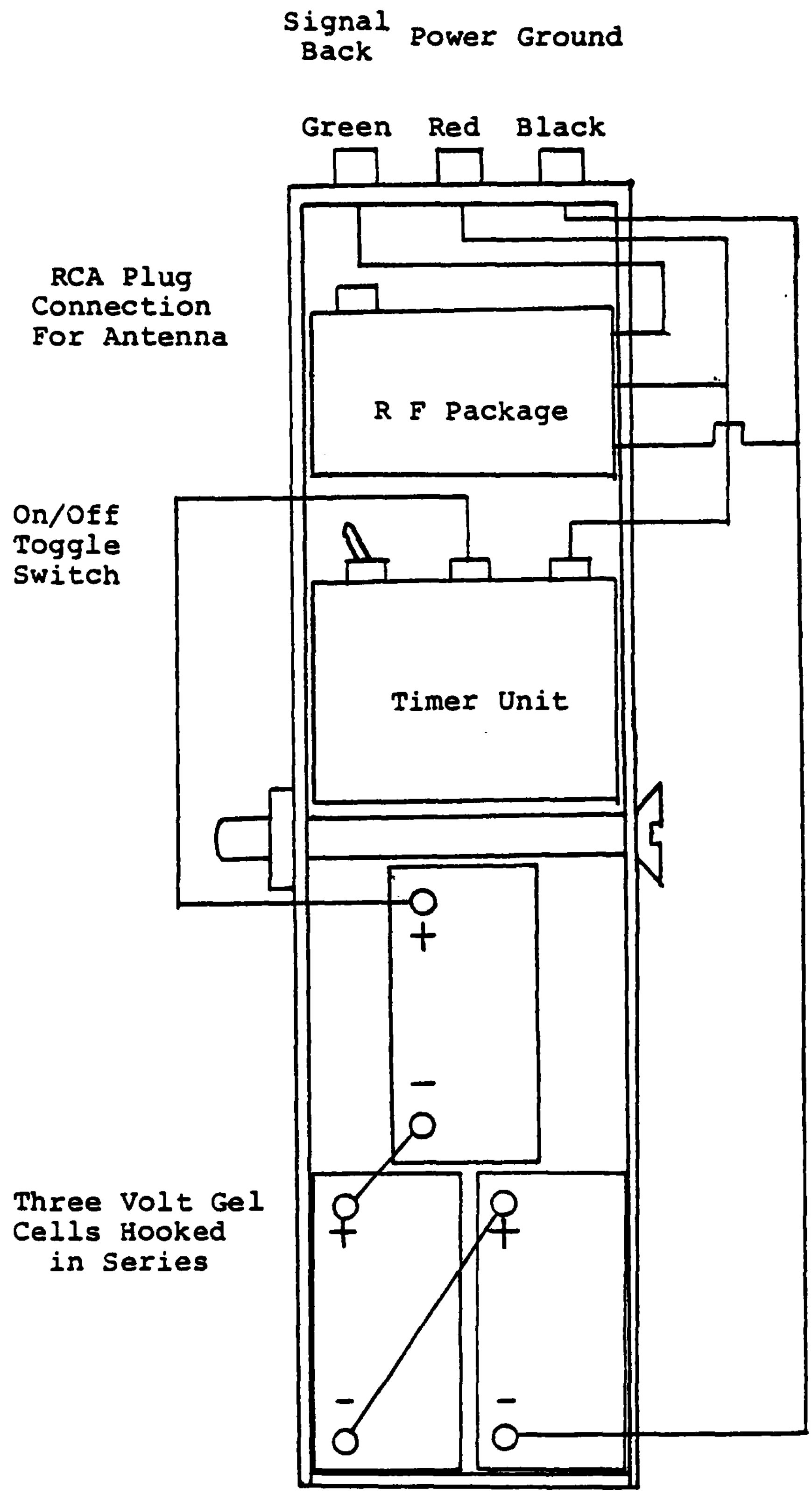

Figure 2-2: Arrangement of Topside Electronic Package

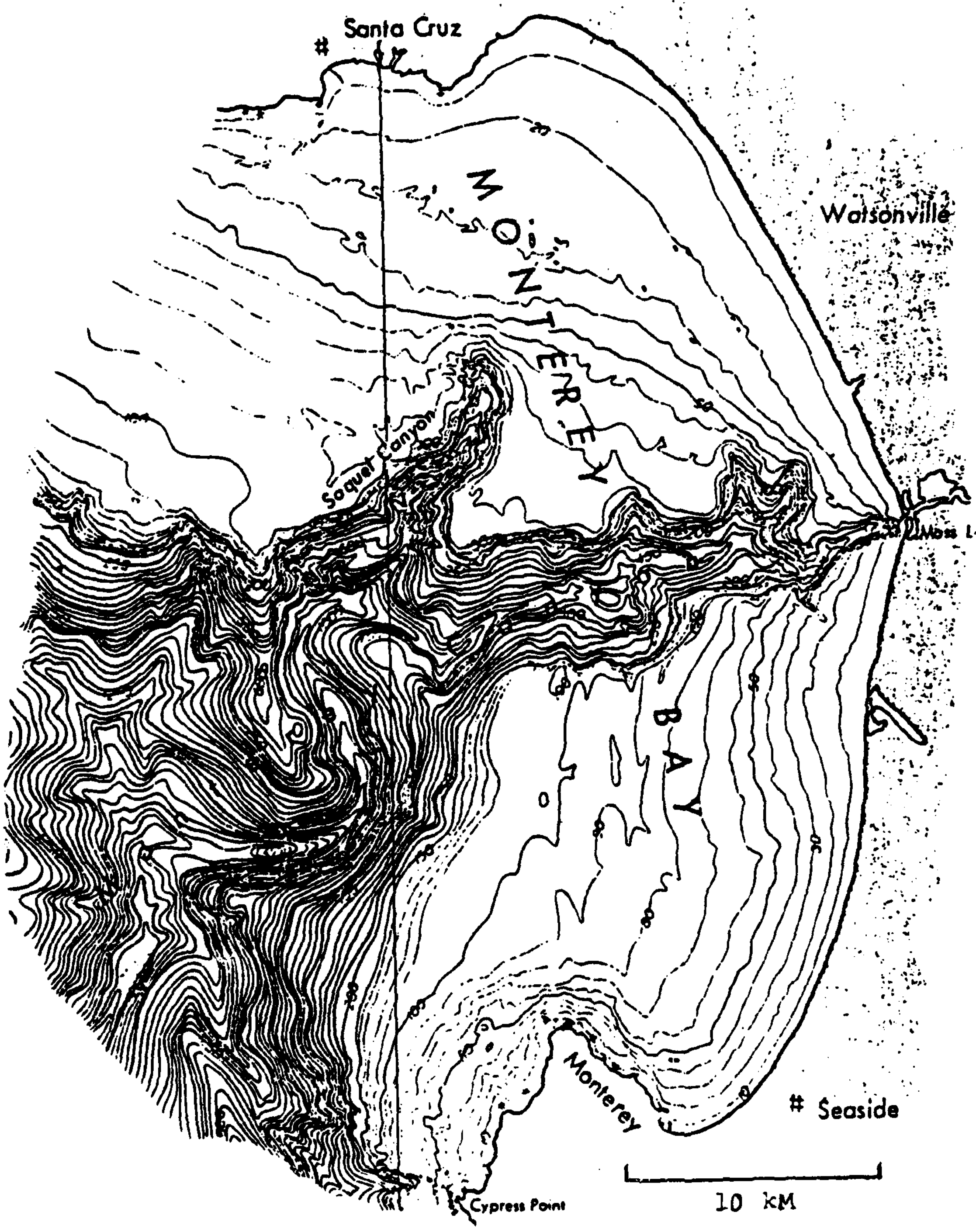

Figure 2-3: Chart of Monterey Bay

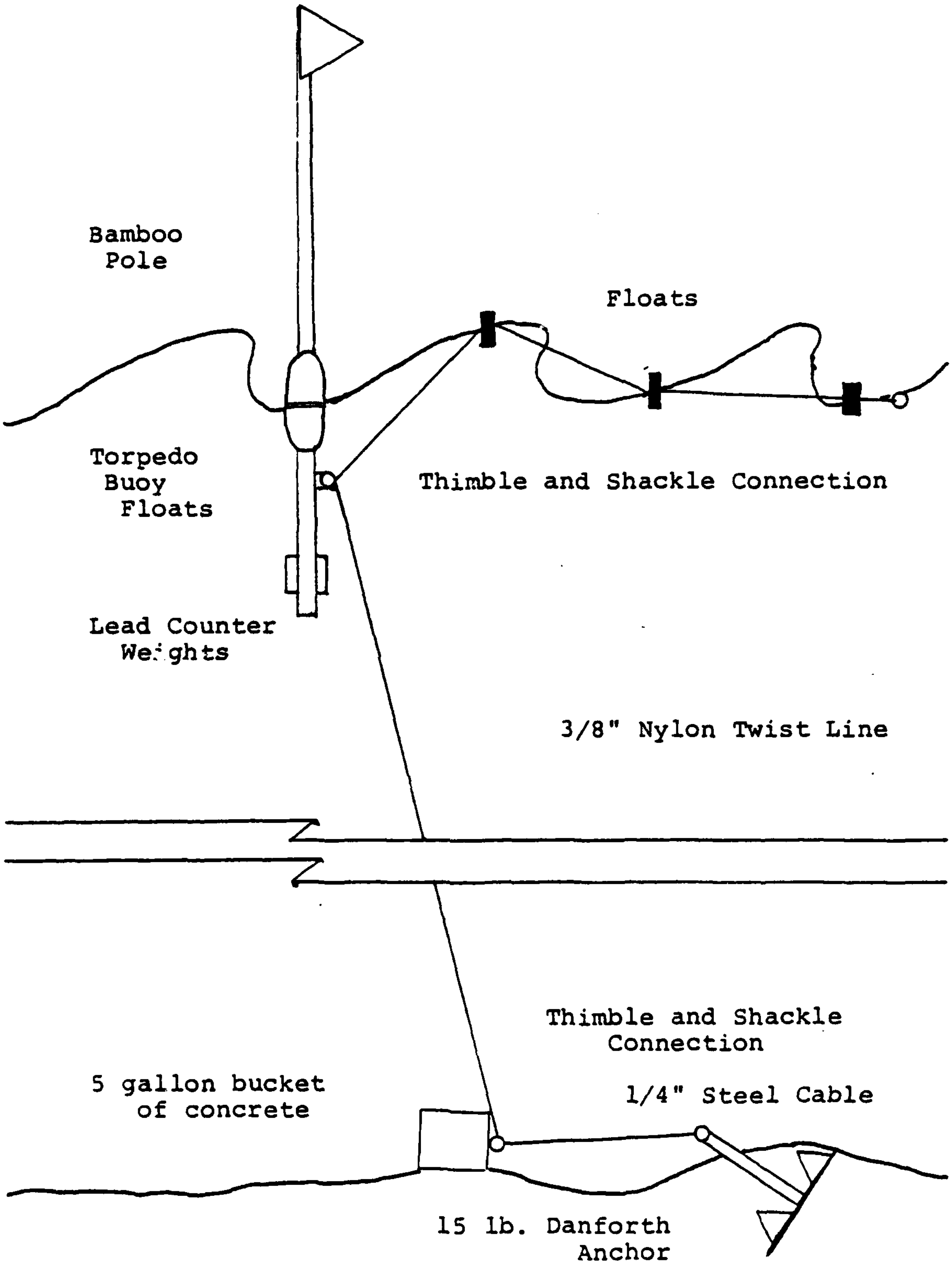

Figure 2-4: First Anchoring System

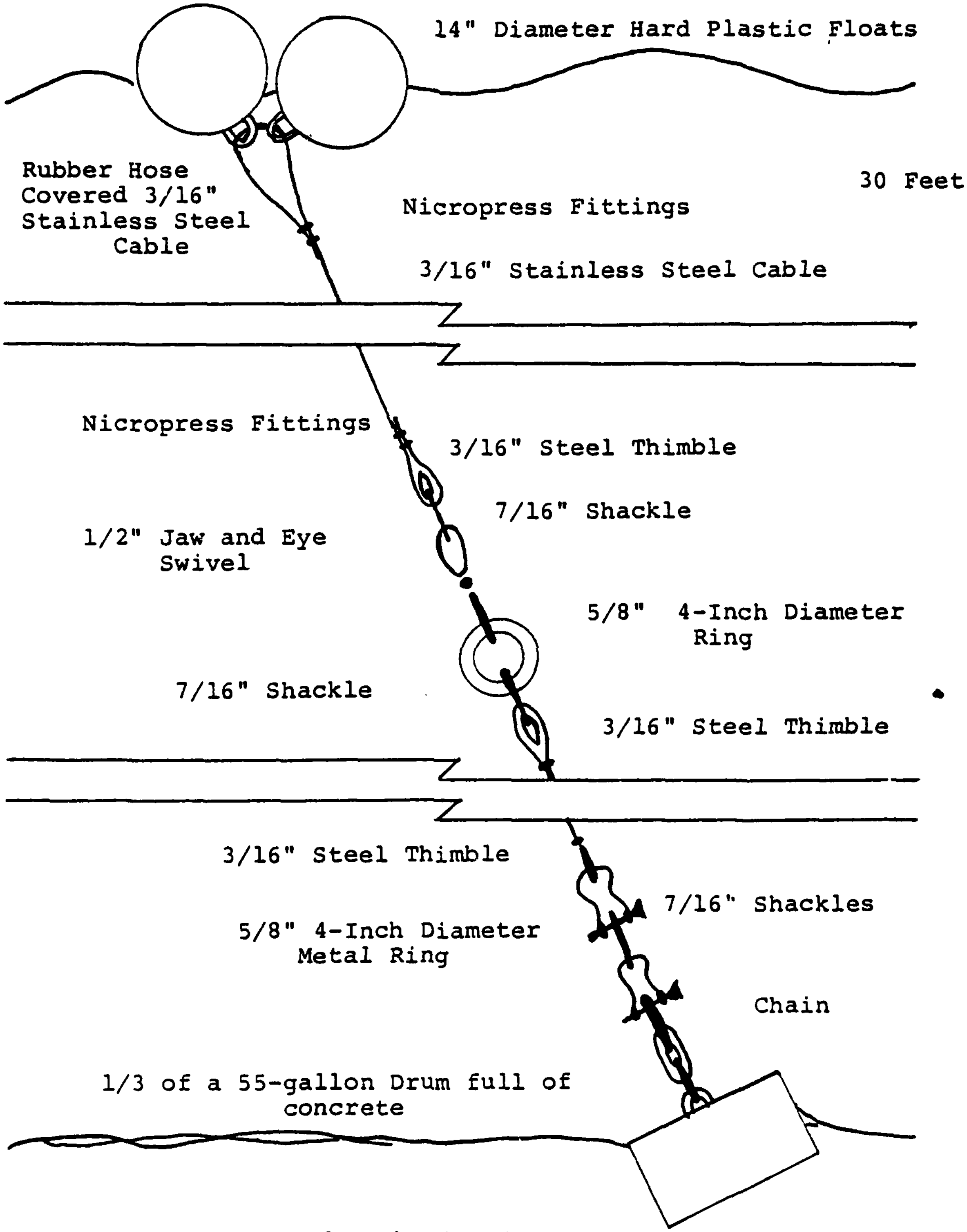

Figure 2-5: Second Anchoring System

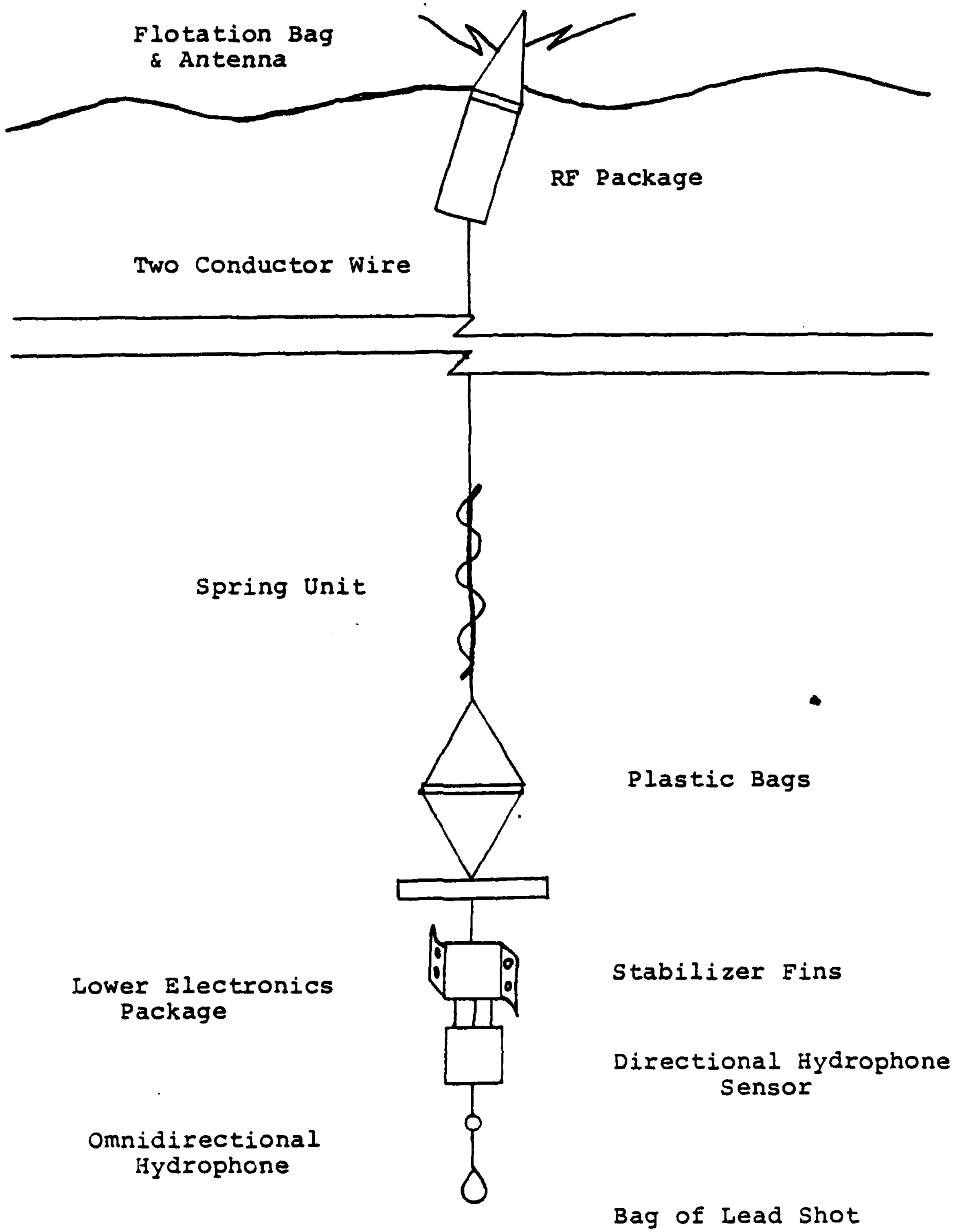

Figure 2-6: Artist Conception of Disposable DIFAR Sonobuoy System

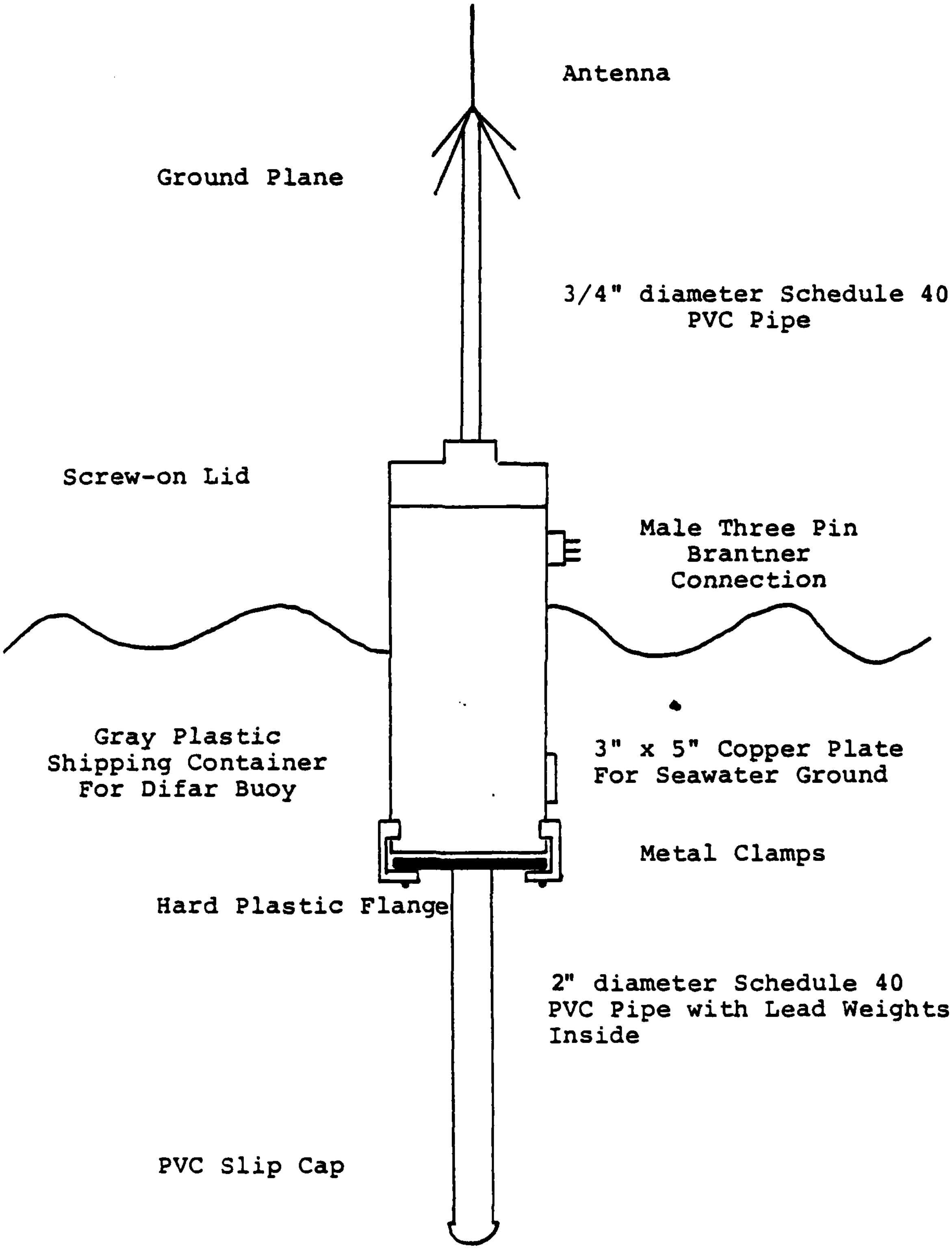

Figure 2-7: Housing for Topside Electronic Package

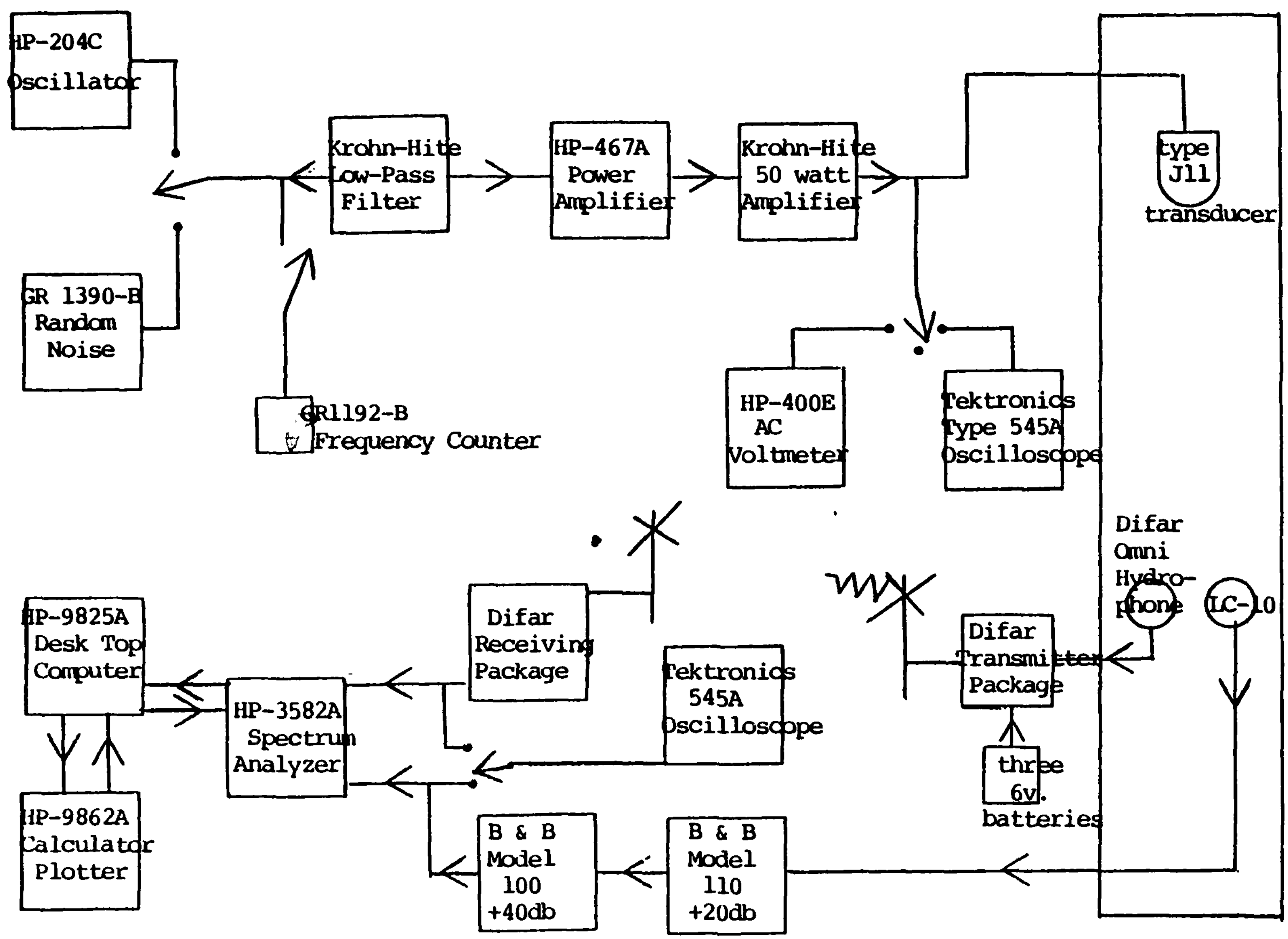

Figure 3-1: Block Diagram of Equipment Setup for 3 Mar 81 to 1 Apr 81 Calibration Operations

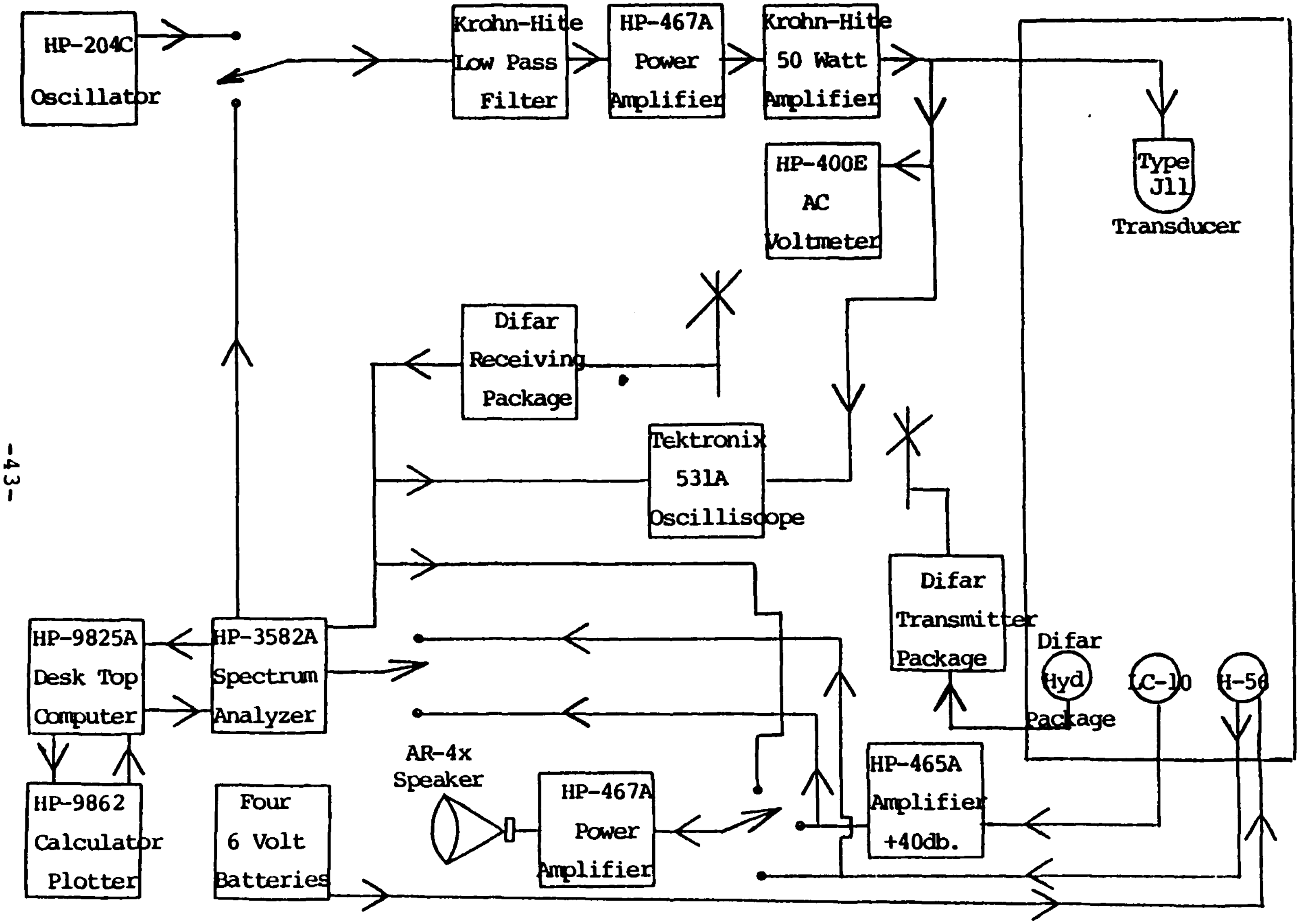

Figure 3-2: Block Diagram of Equipment Setup for 10 Aug 81 to 11 Aug 81 Calibration Operations

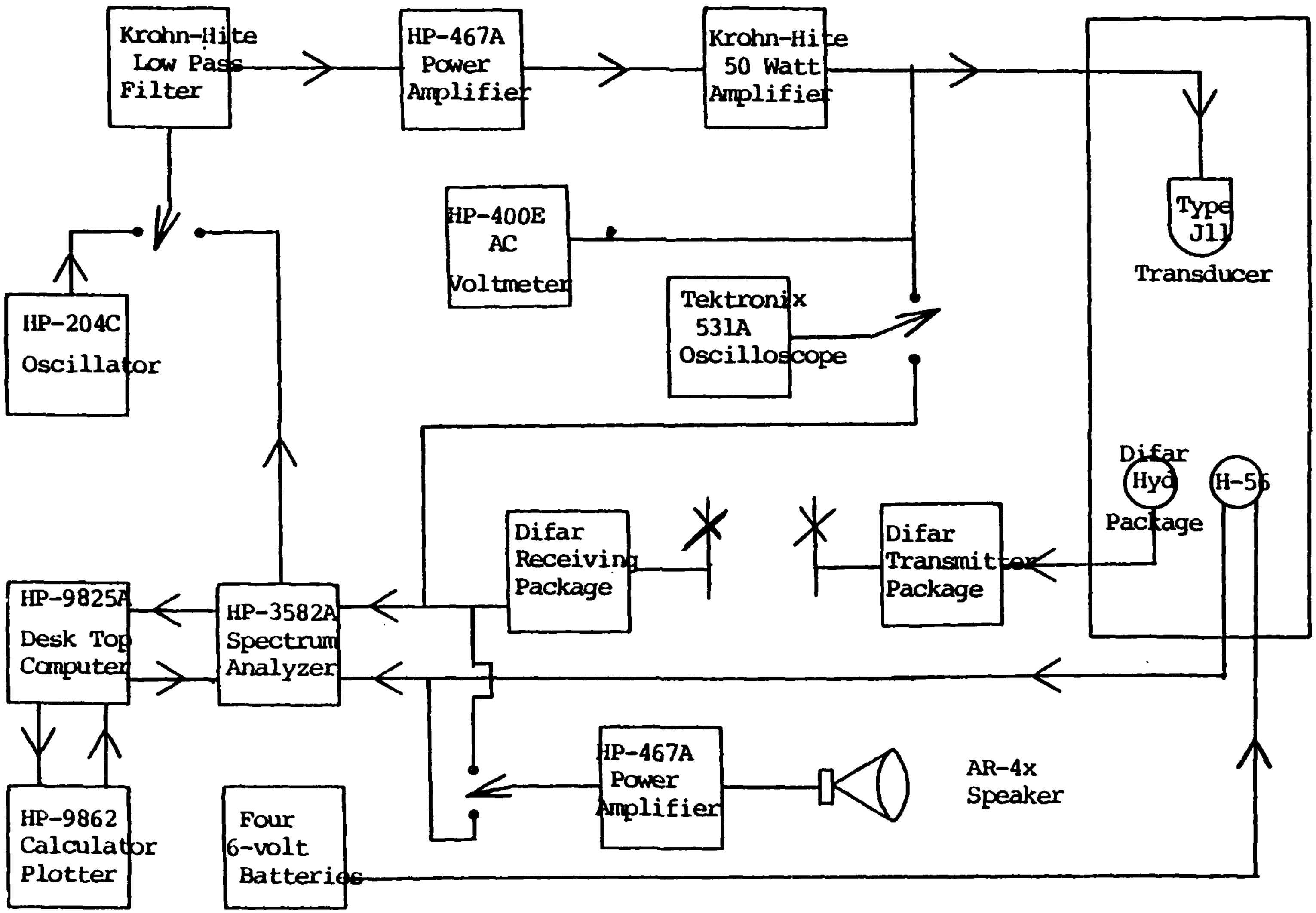

Figure 3-3: Block Diagram of Equipment Setup for 15 Oct 81 to 29 Oct 81 Calibration Operations

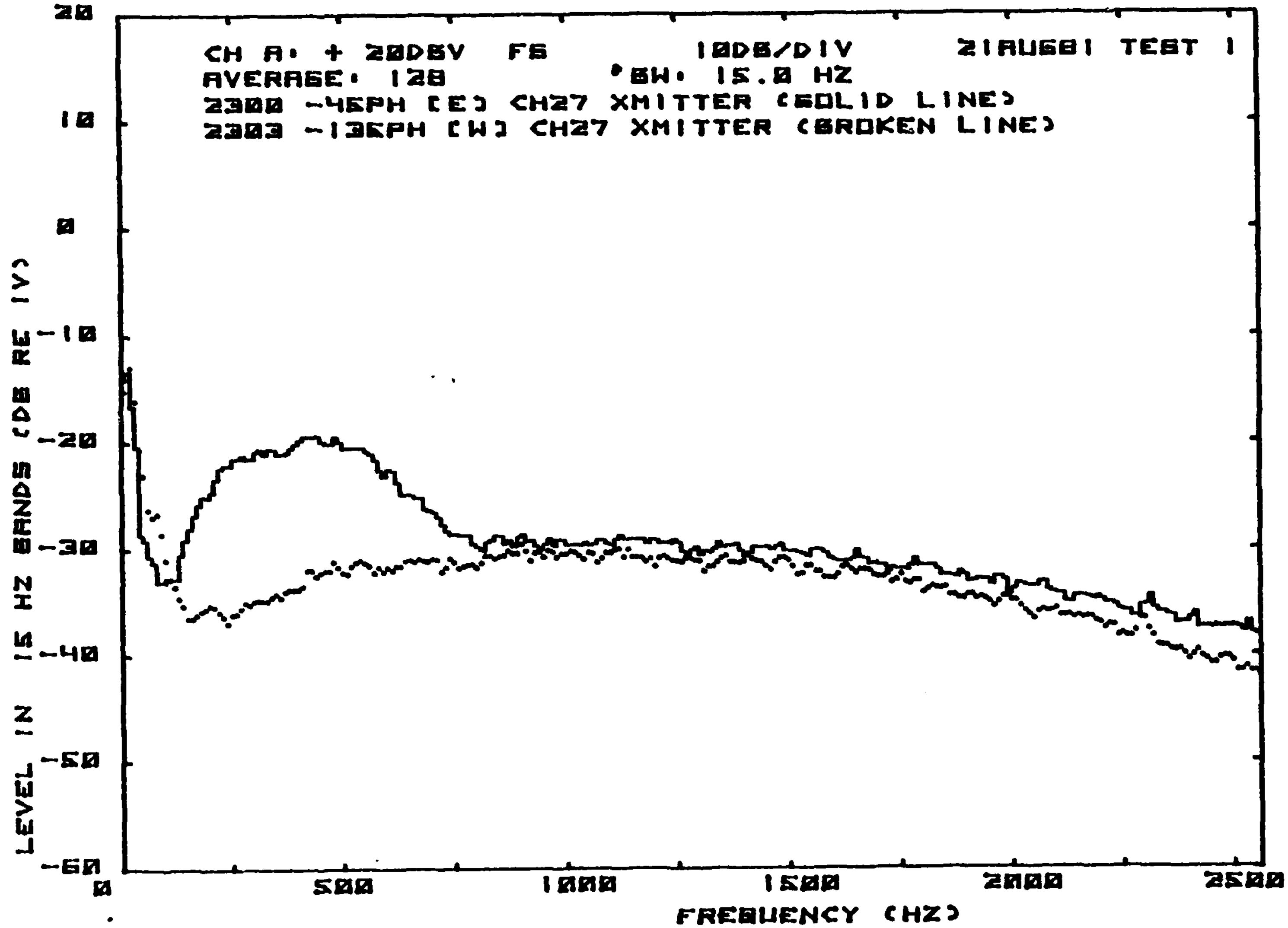

Figure 4-1: Graph of Typical Directional Data

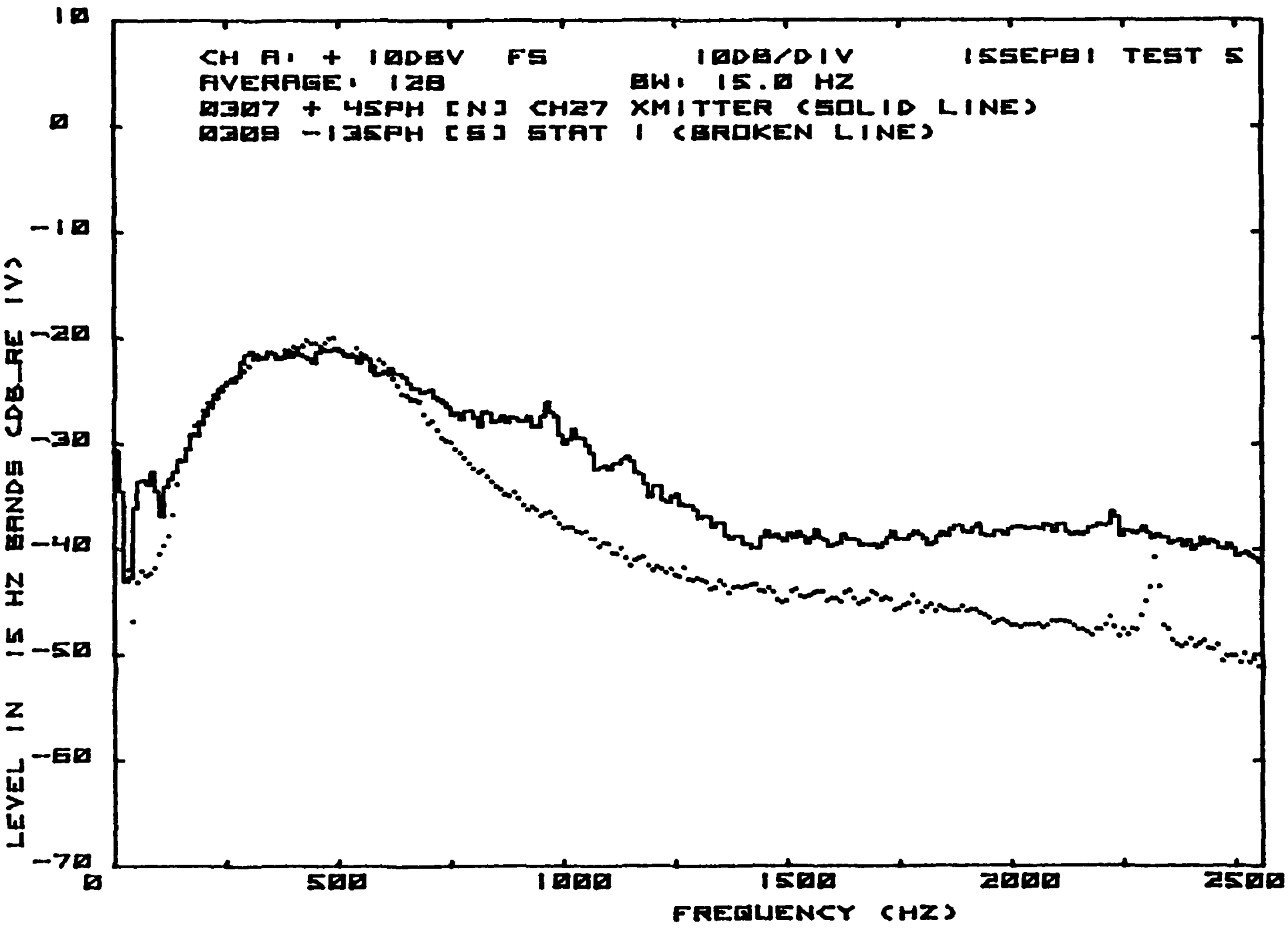

Figure 4-2: Graph of Typical Directional Data

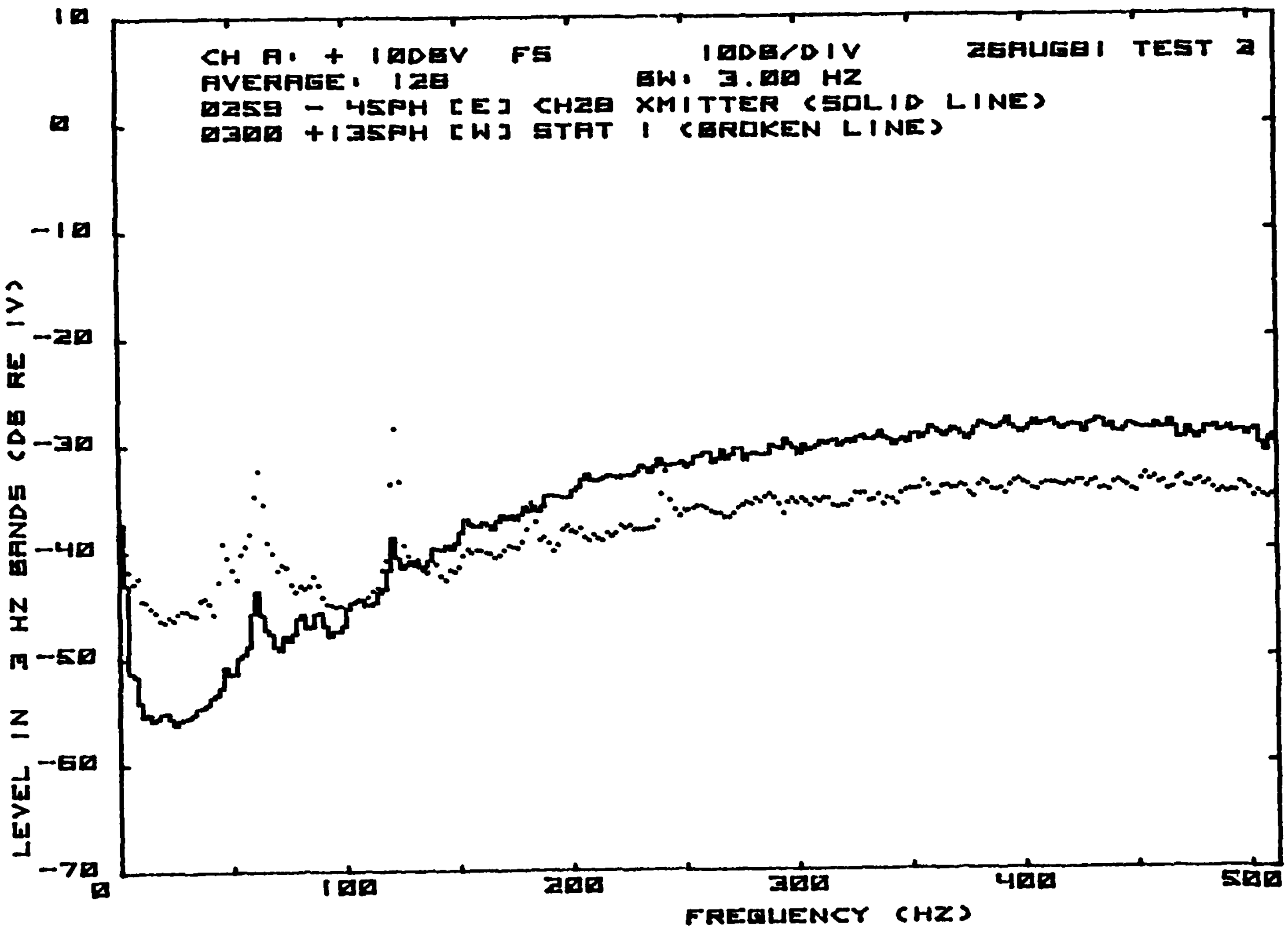

Figure 4-3: Graph of Typical Directional Data

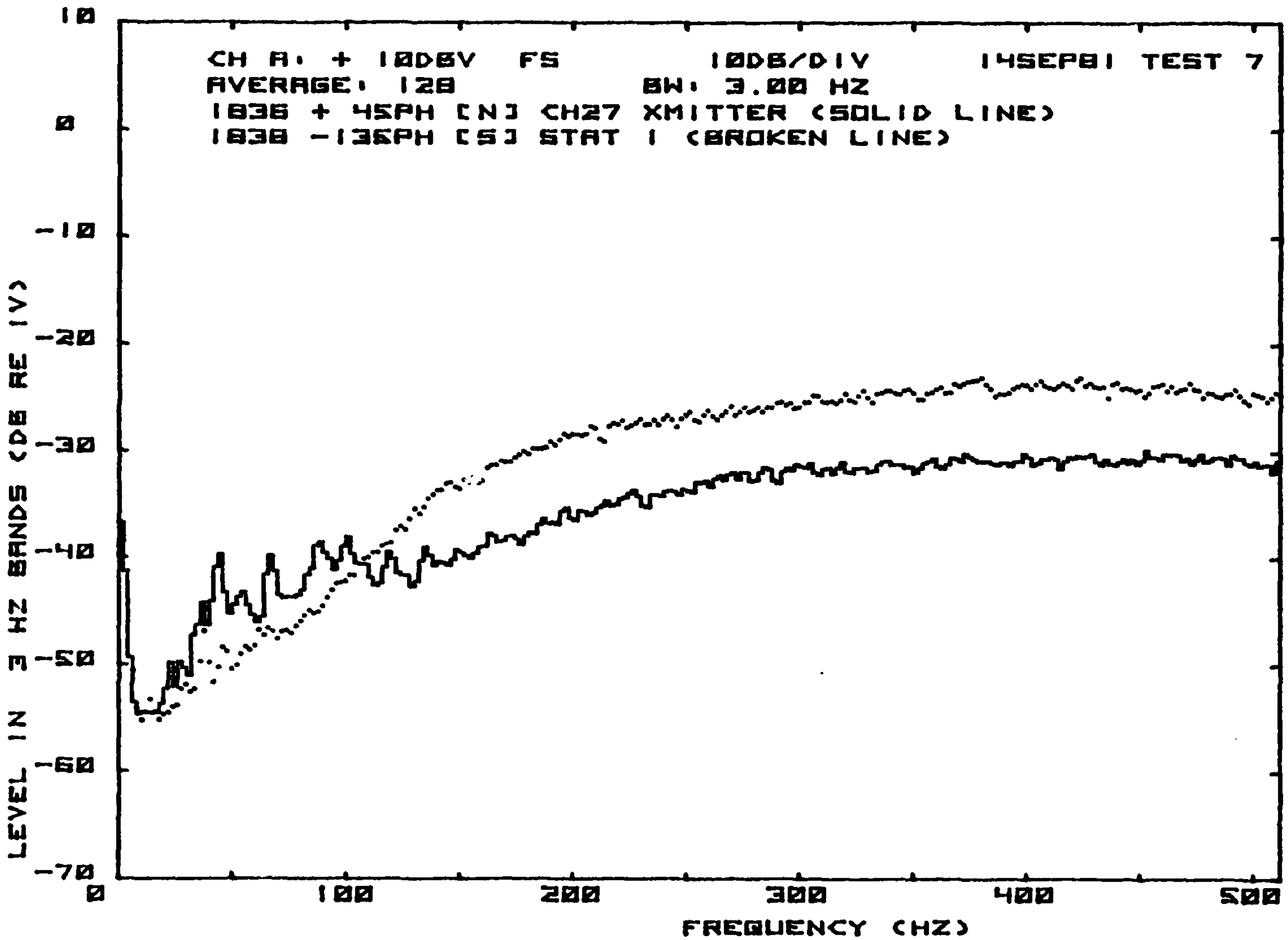

Figure 4-4: Graph of Typical Directional Data

```
26AUG81 TEST 3
WIND DIRECTION= NW
WAVE HEIGHT FT = 3-5
SWELL HEIGHT FT = 4-7
SWELL DIRECTION = NW
TIME OF CLOSEST HIGH TIDE = 0938
TIME OF CLOSEST LOW TIDE = 0243
CURRENT TIDE = SLACK
AVERAGE DIFFERENCE IN DB IS =  2
```

Figure 4-5: Example of Environmental Data Stored

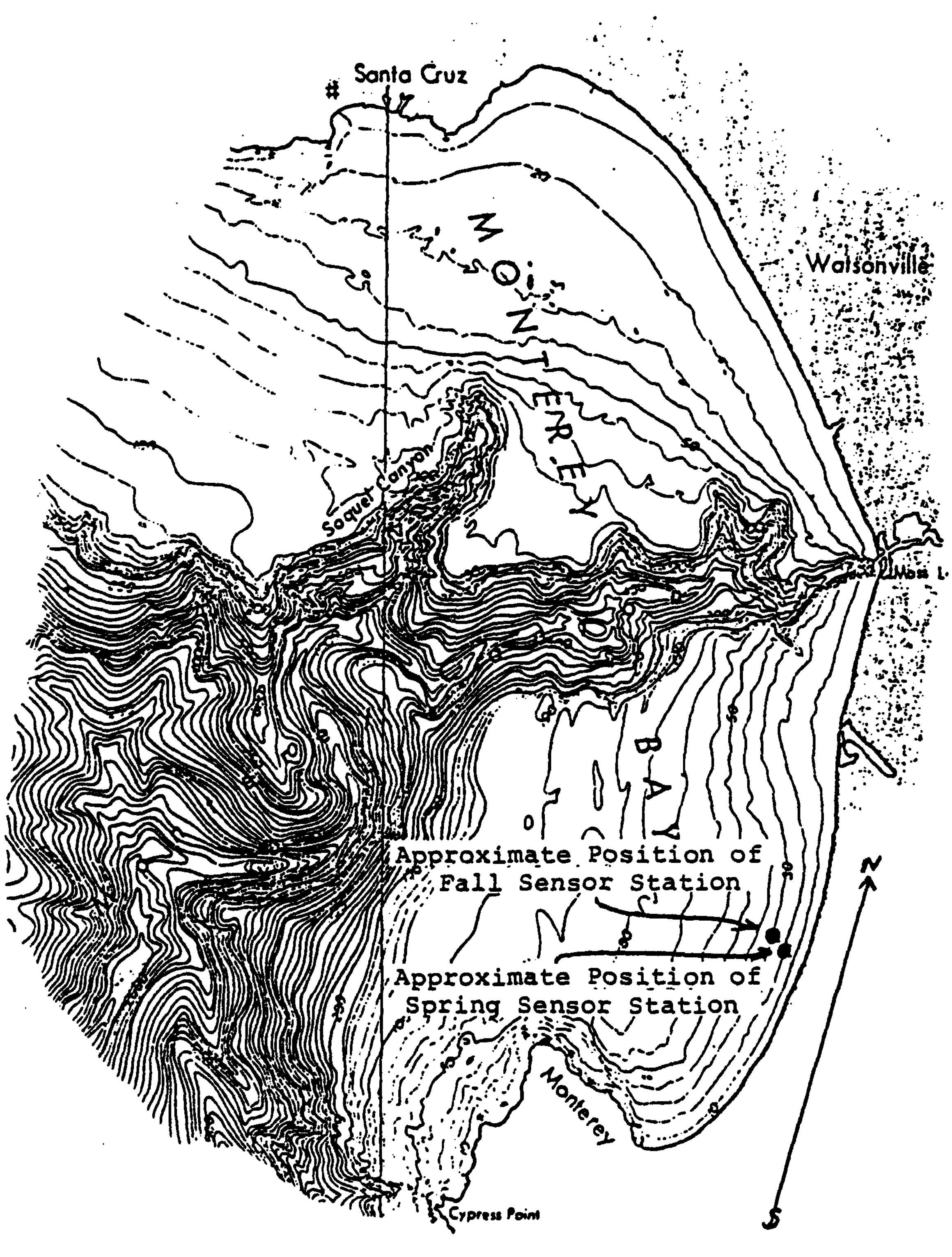

Figure 4-6: Sensor Placement Chart

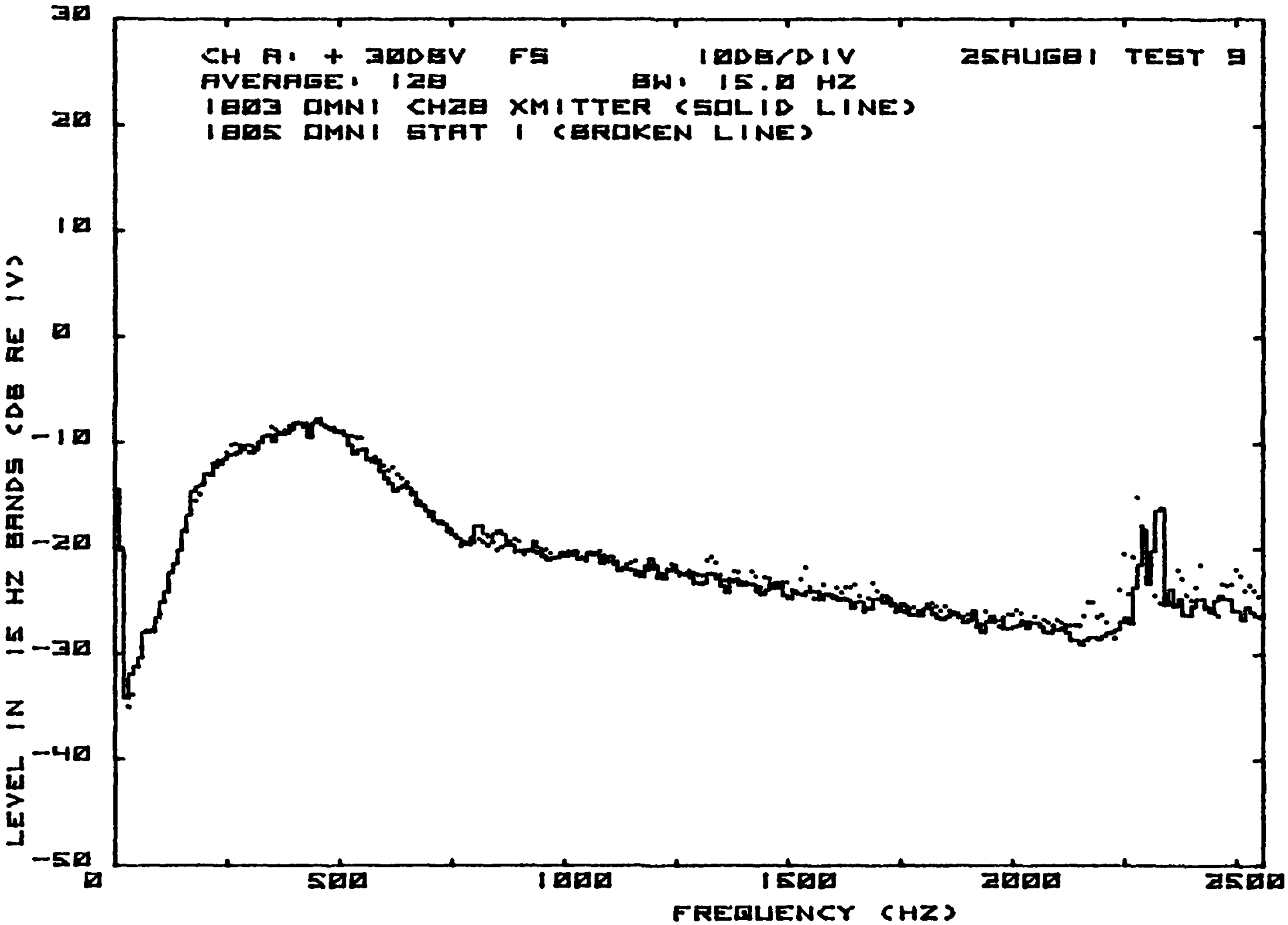

Figure 4-7: Graph of Typical Omnidirectional Data

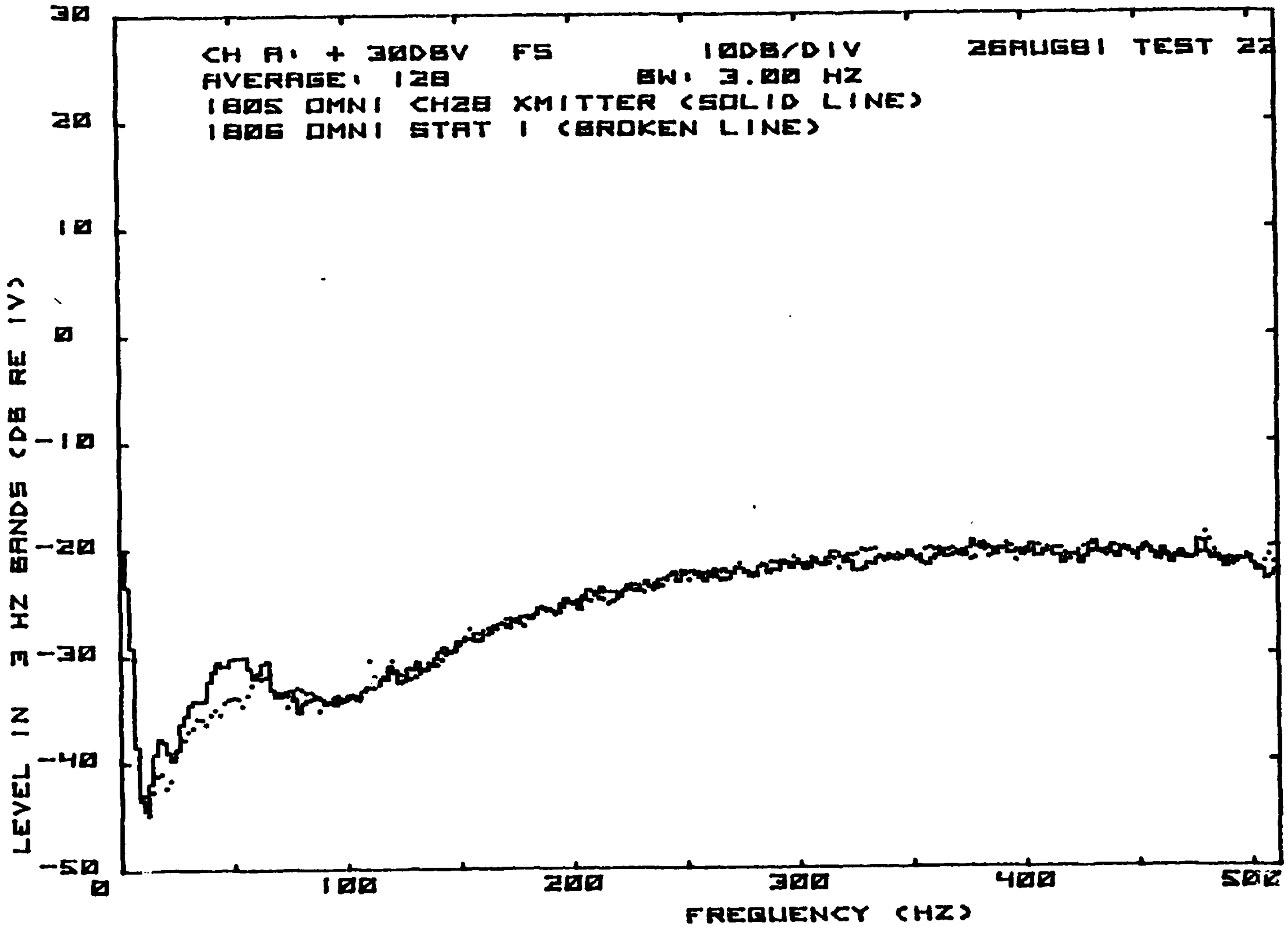

Figure 4-8: Graph of Typical Omnidirectional Data

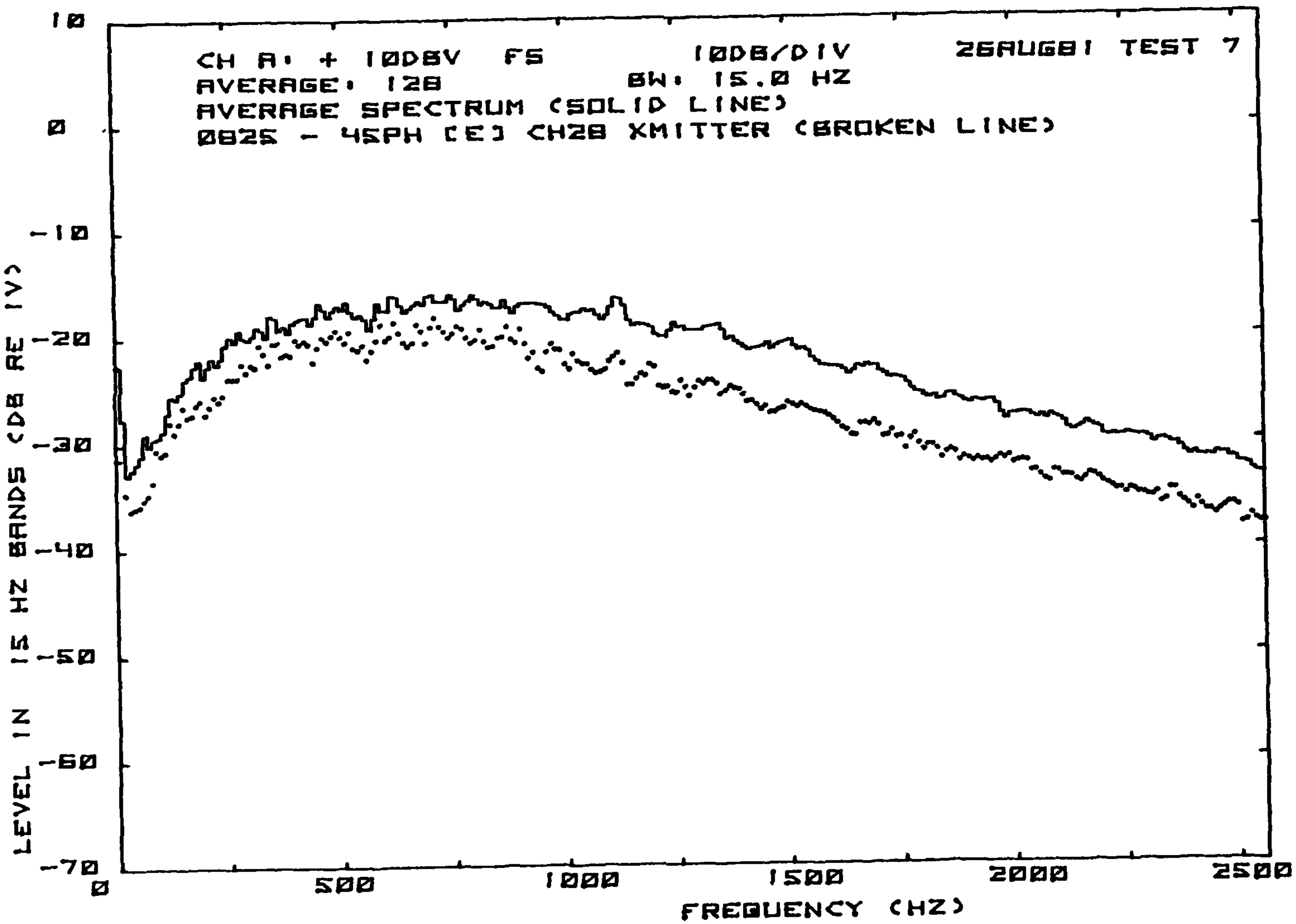

Figure 4-9: Graph of Typical Average and Directional Spectrum

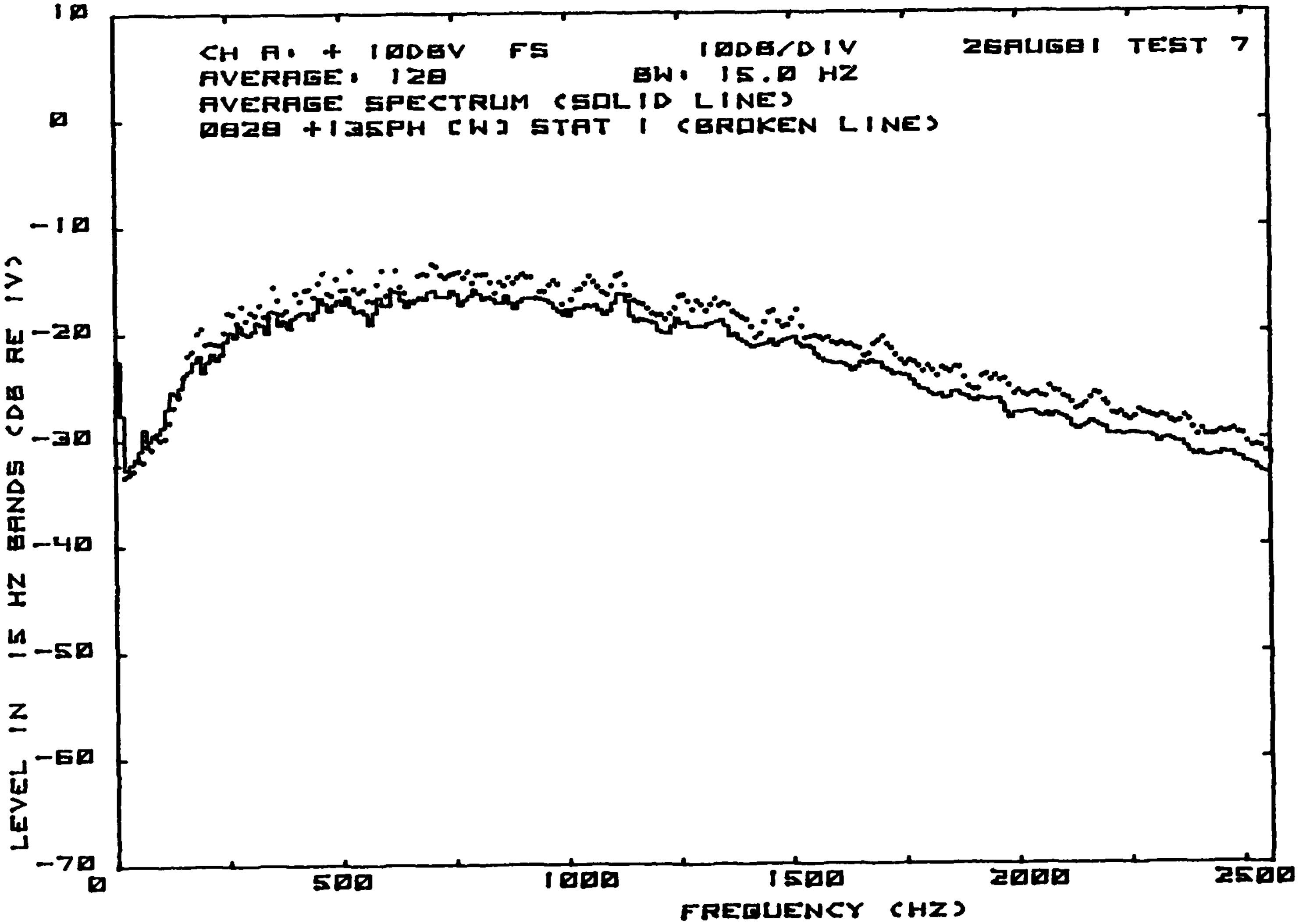

Figure 4-10: Graph of Typical Average and Directional Data

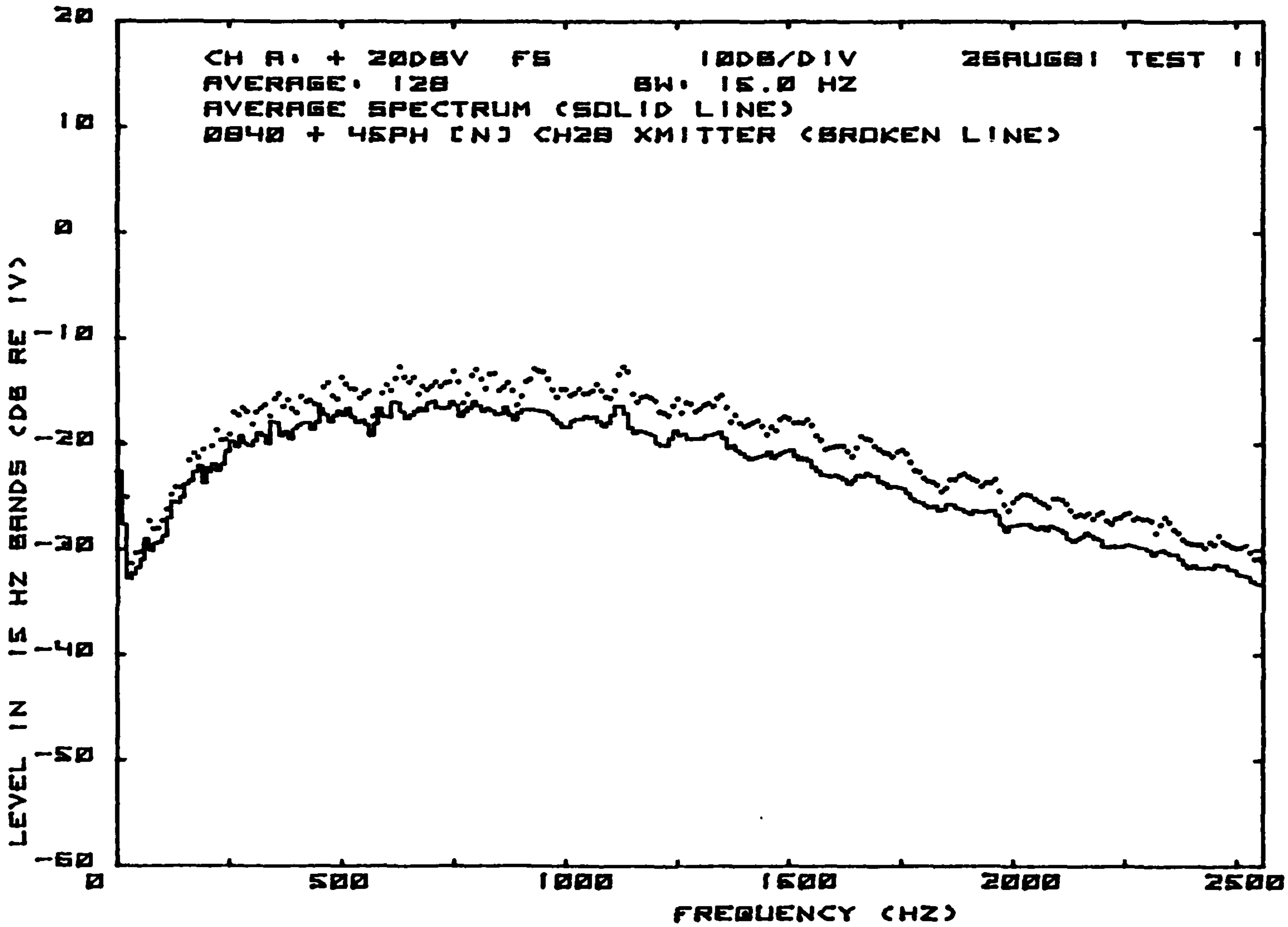

Figure 4-11: Graph of Typical Average and Directional Spectrum

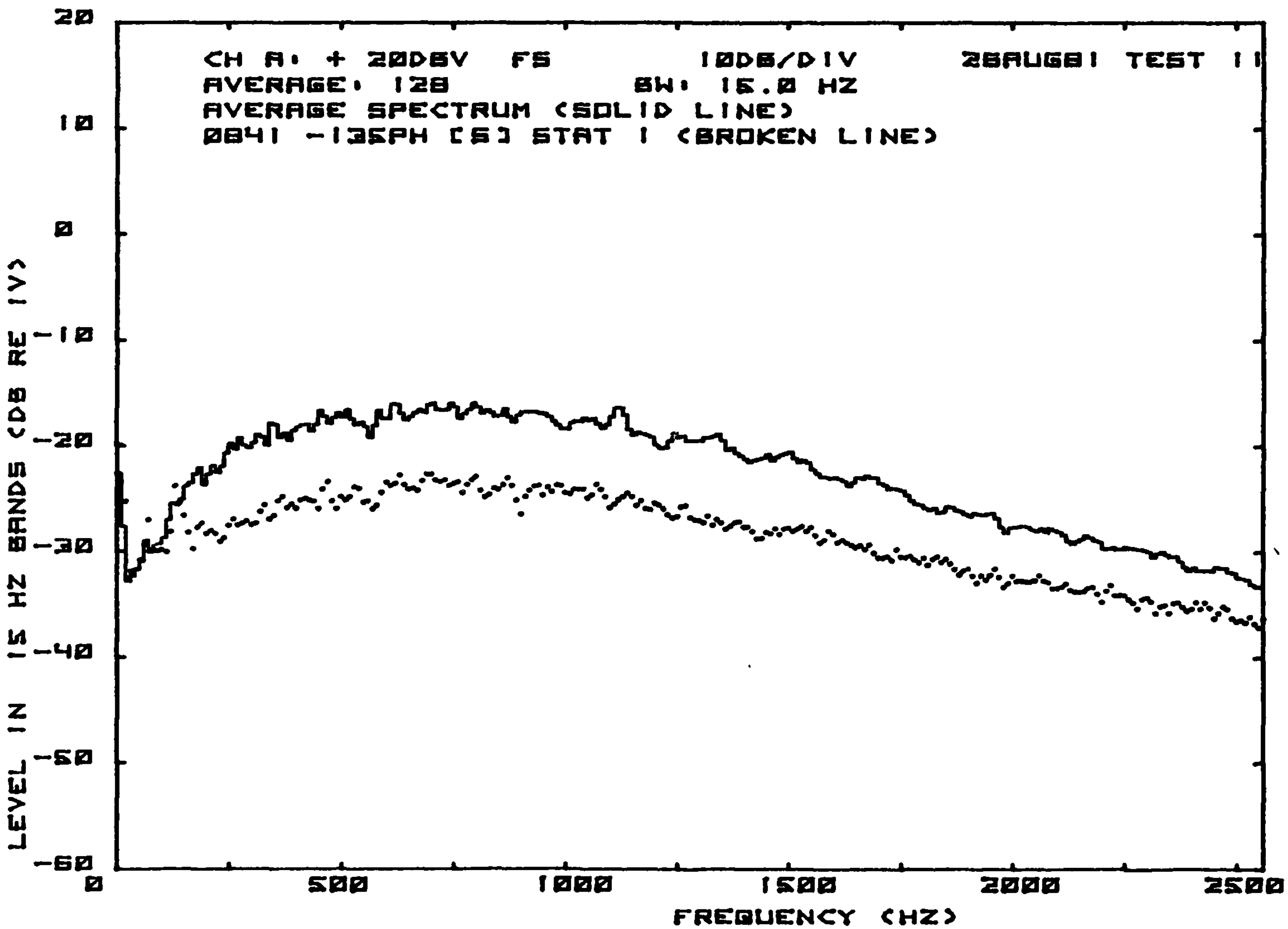

Figure 4-12: Graph of Typical Average and Directional Spectrum

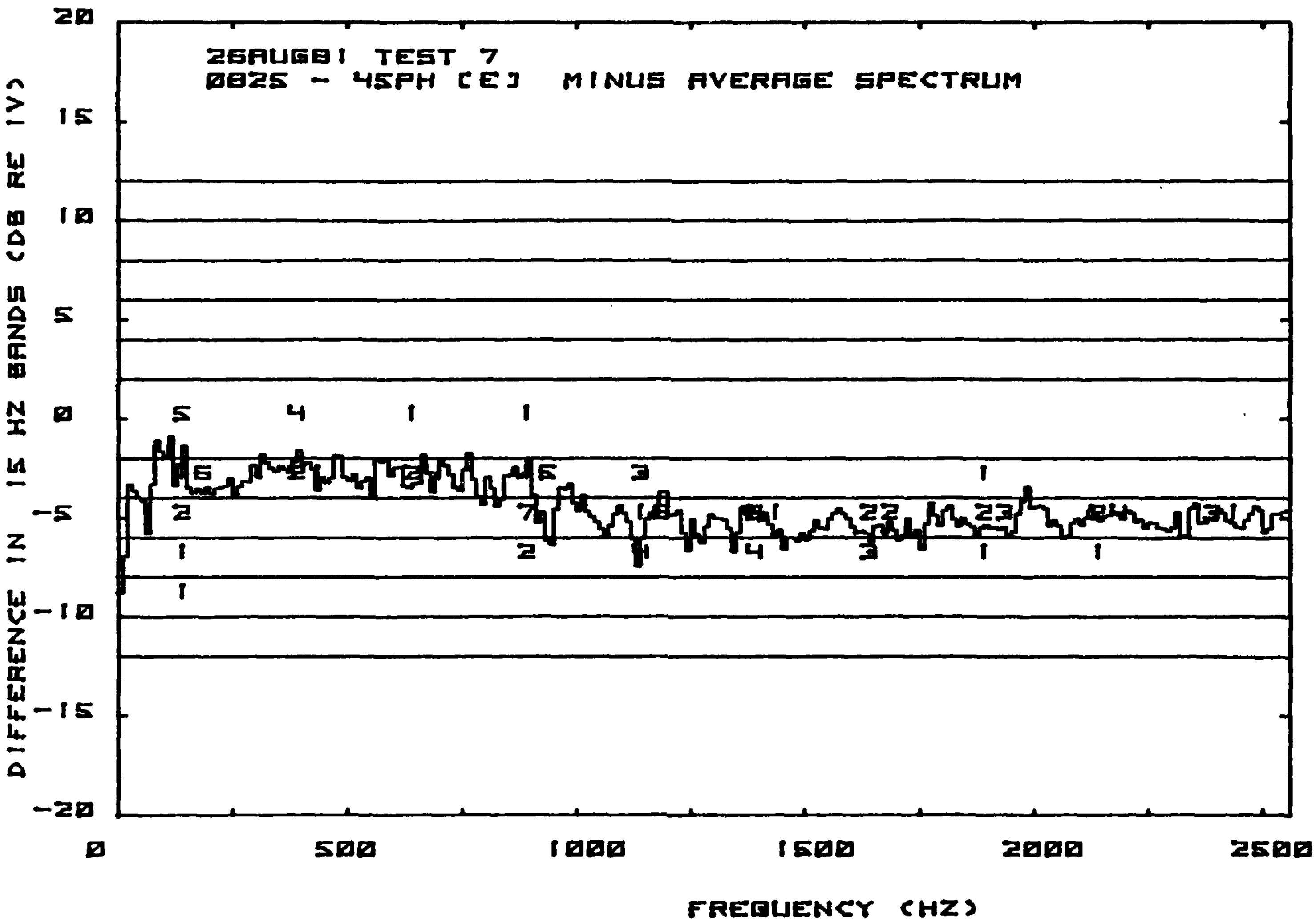

Figure 4-13: Graph of the Directional Bin Energy Minus the Level of the Average Bin Energy

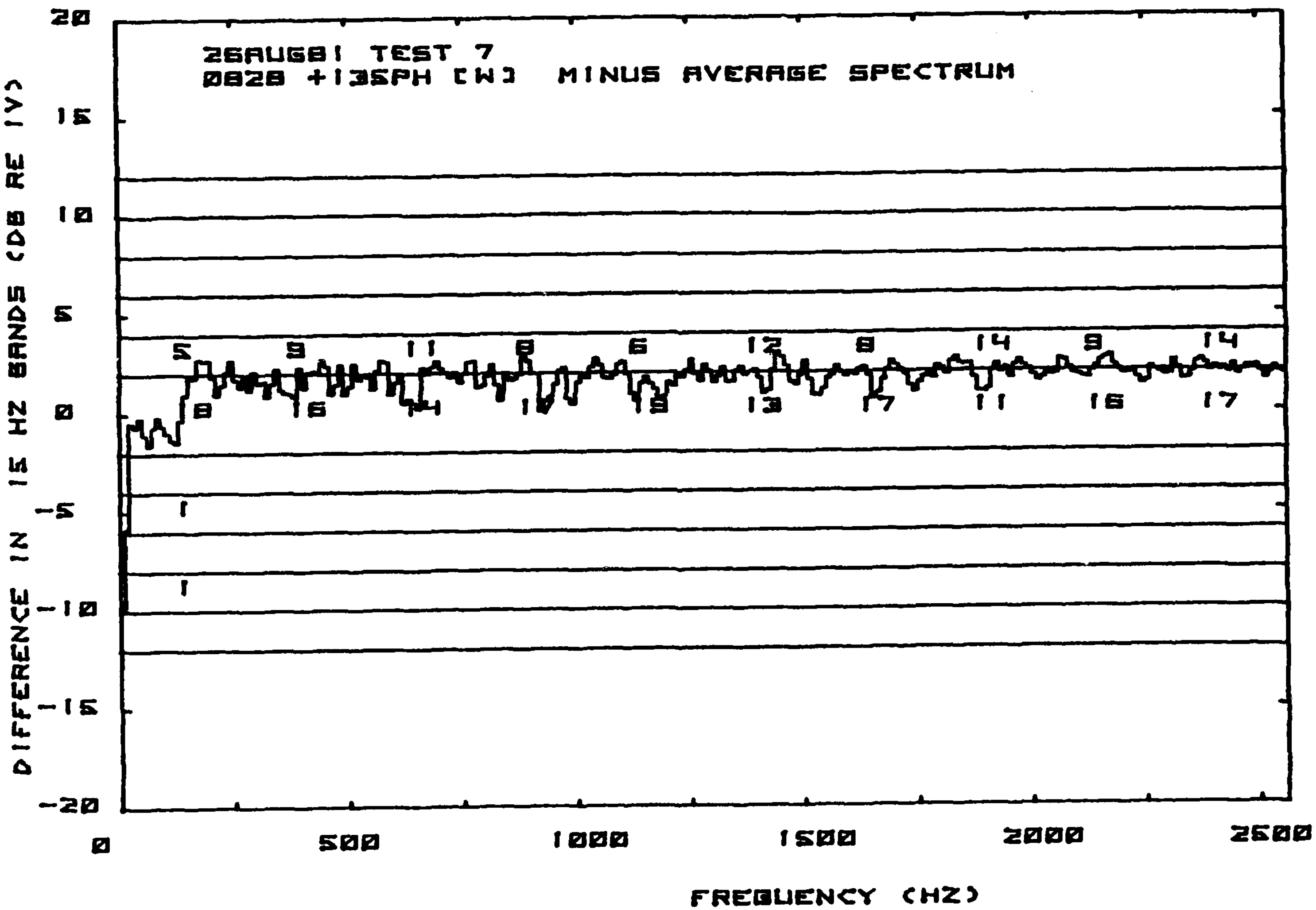

Figure 4-14: Graph of the Directional Bin Level Minus the Level of the Average Bin Energy

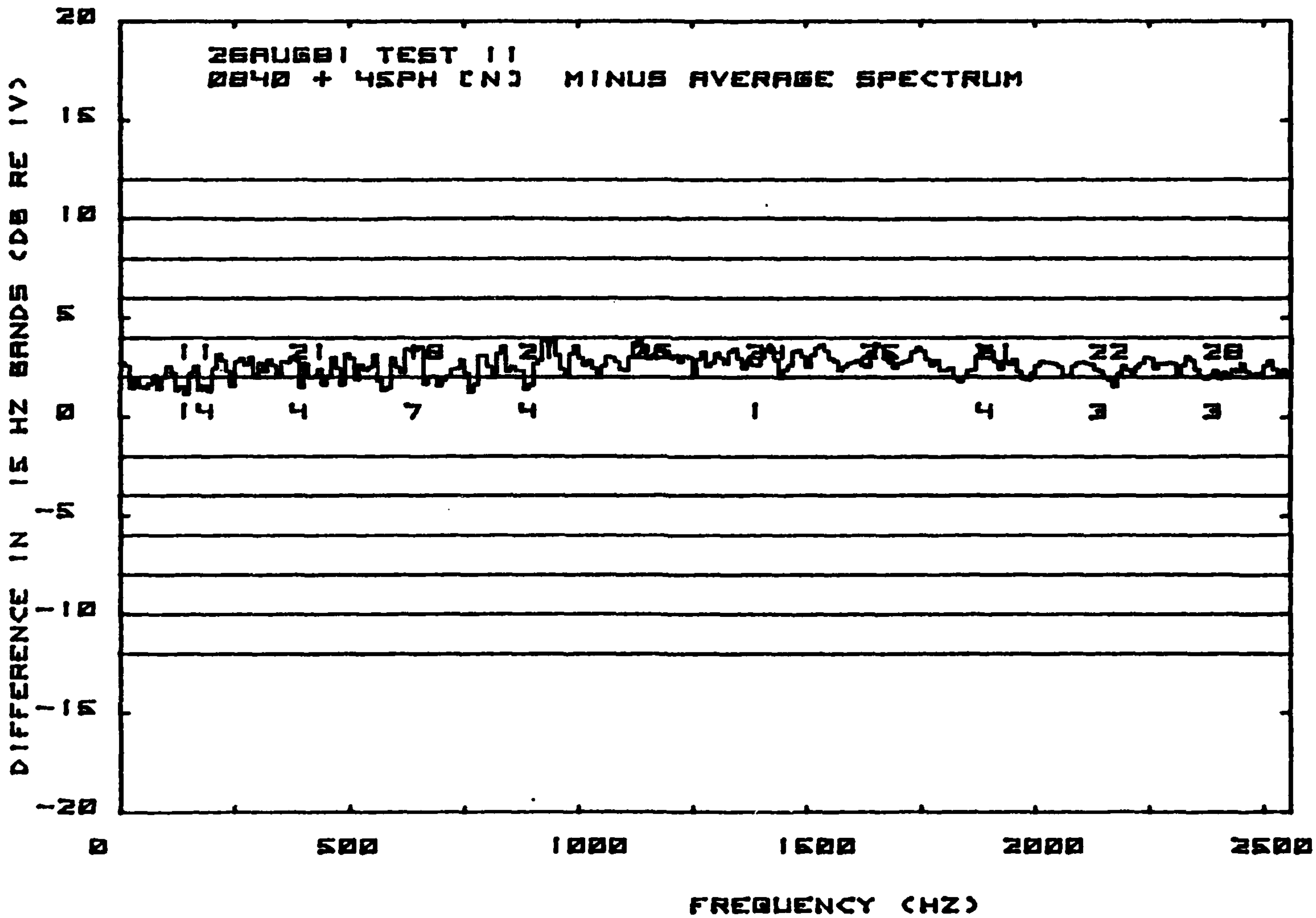

Figure 4-15: Graph of the Directional Bin Level Minus the Level of the Average Bin Energy

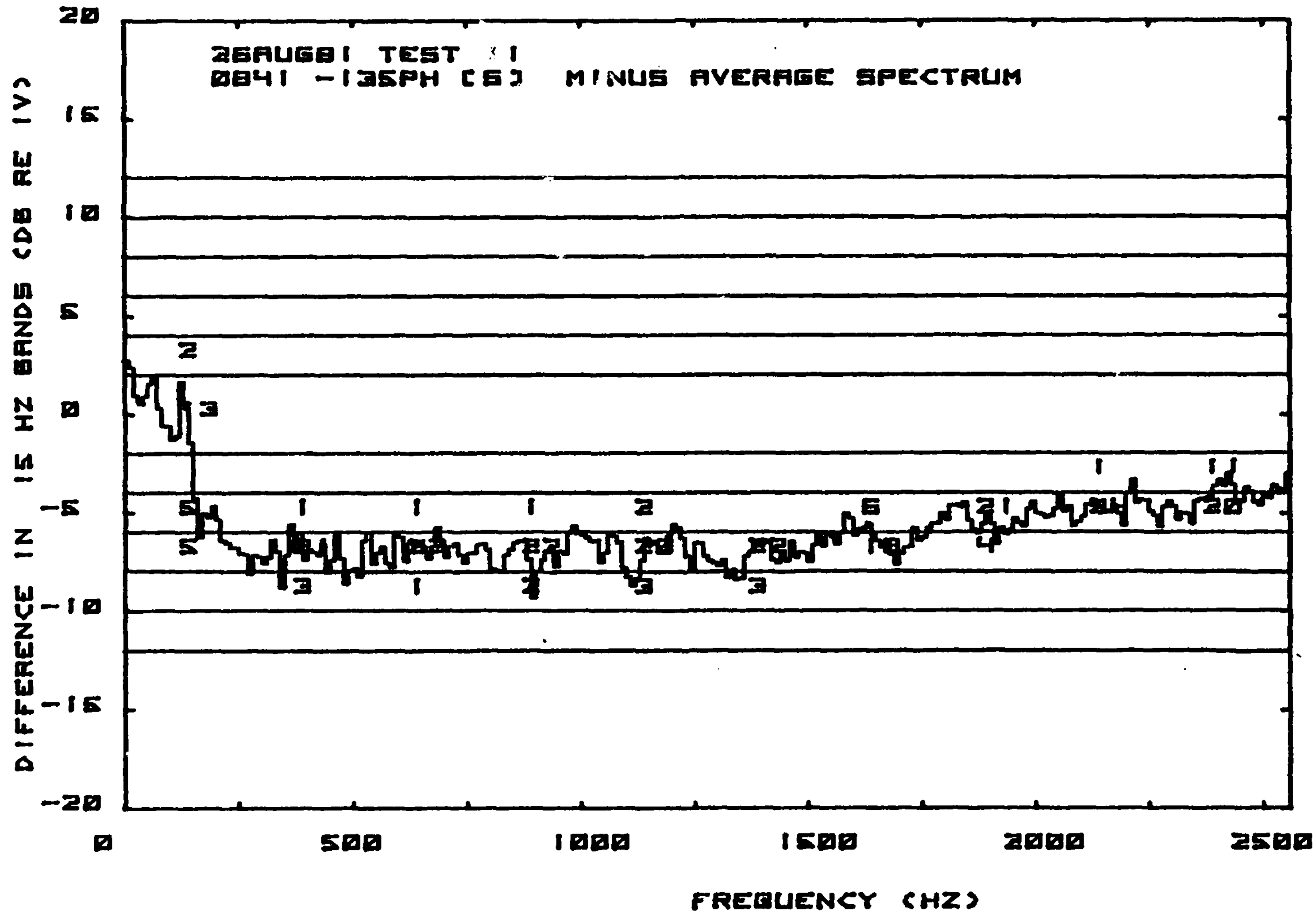

Figure 4-16: Graph of the Directional Bin Level Minus the Level of the Average Bin Energy

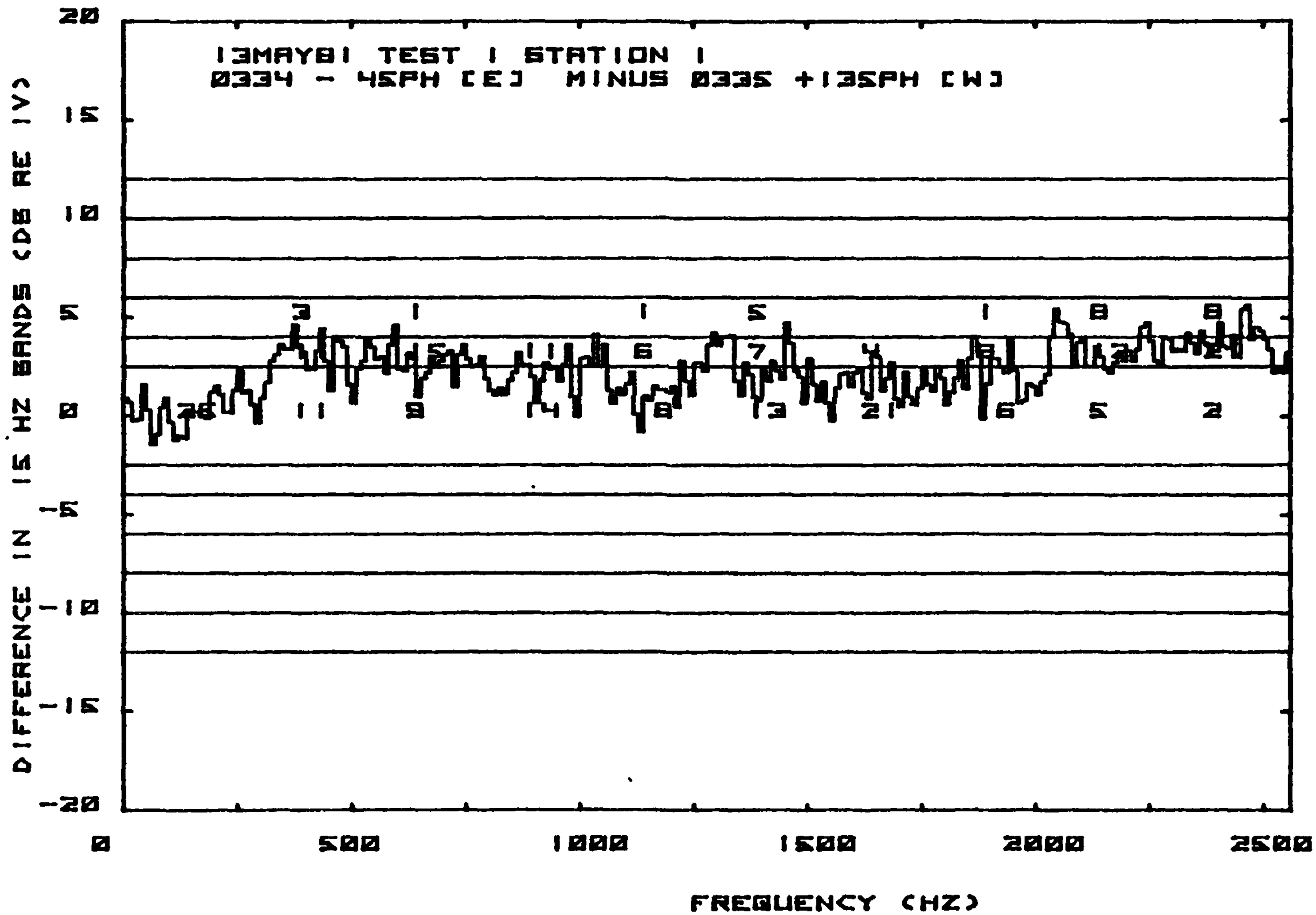

Figure 4-17: Graph of the Directional Bin Level East Minus the Directional Bin Level West, 0 to 2500 Hz

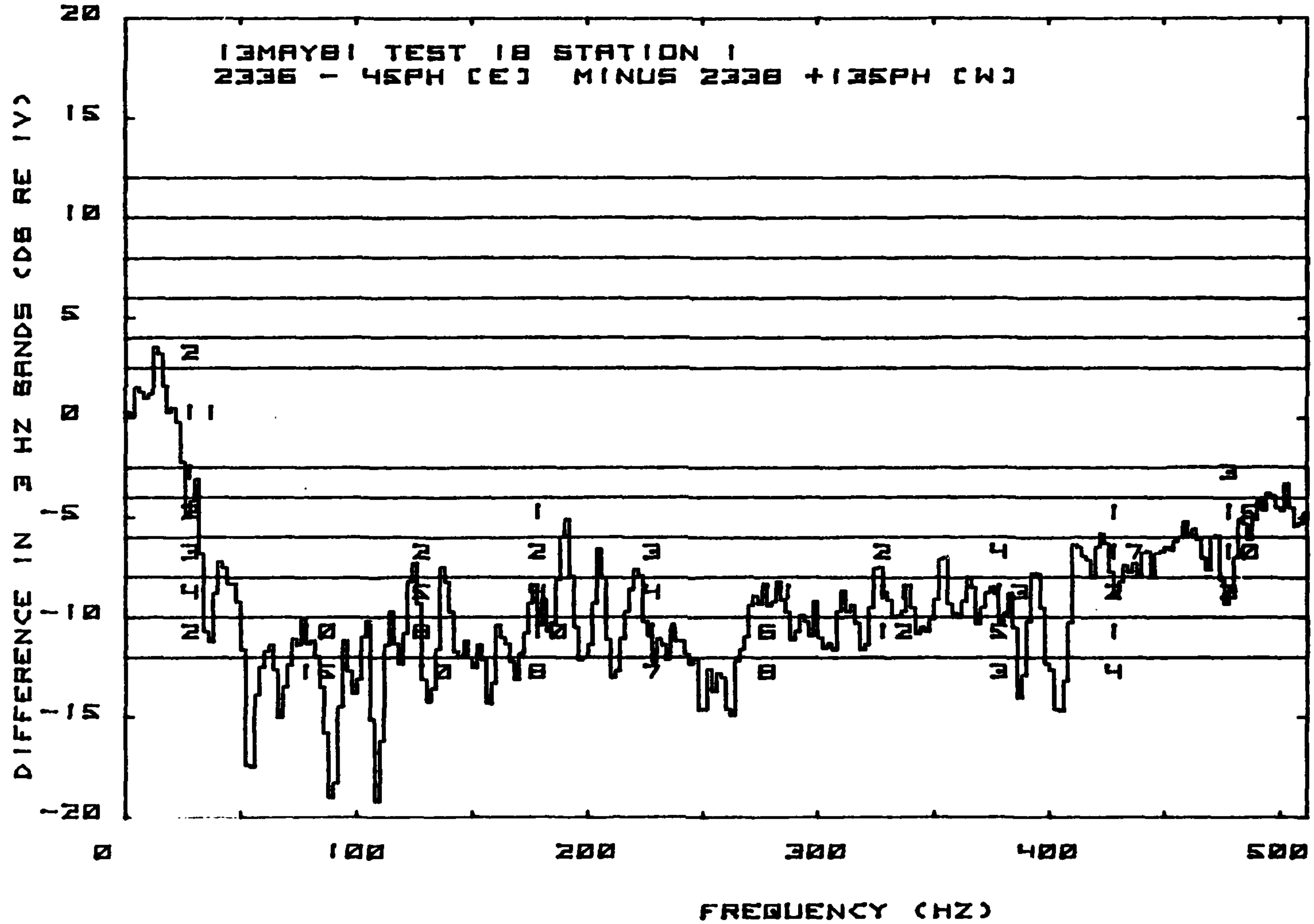

Figure 4-18: Graph of the Directional Bin Level East minus the Directional Bin Level West, 0 to 500 Hz

Direction	Frequency Band	0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+	1	1	1							
EAST	0			1	2	2	2	2	3	3	3
	-	2	2	1	1	1	1	1			
	+	1	1	1	1	1	1	1	1	1	1
WEST	0	2	2	2	2	2	2	2	2	2	2
	-										
	+		1								
NORTH	0	2	1	2	2	2	2	2	2	2	2
	-	1	1	1	1	1	1	1	1	1	1
	+										
SOUTH	0	2	2	2	2	2	2	2	2	2	2
	-	1	1	1	1	1	1	1	1	1	1

Table 4-1: Analysis of 0 to 500 Hz data recorded during 0300 sessions in the Spring of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+						1	1	1	1	1
EAST	0	2	4	3	3	3	2	1	1	1	2
	-	2		1	1	1	1	2	2	2	1
	+										
WEST	0	3	2	2	3	2	2	2	2	2	2
	-	1	2	2	1	2	2	2	2	2	2
	+		1	2	1	1	1	2	1	1	2
NORTH	0	4	3	2	3	3	3	1	2	2	1
	-							1	1	1	1
	+	2	1								
SOUTH	0	2	2	3	3	3	4	4	4	4	3
	-		1	1	1	1					1

Table 4-2: Analysis of 0 to 500 Hz data recorded during 0800 sessions in the Spring of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+					1				1	
EAST	0	2	2	2	2	1	2	2	2	1	2
	–										
	+										
WEST	0	2	1	2	1	1	1	1	1	1	1
	–		1		1	1	1	1	1	1	1
	+	1		1	1	1	1	1	1	1	1
NORTH	0	1	2	1			1	1	1	1	1
	–				1	1					
	+										
SOUTH	0	2	1								
	–		1	2	2	2	2	2	2	2	2

Table 4-3: Analysis of 0 to 500 Hz data recorded during 1300 sessions in the Spring of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+										
EAST	0	2	2	2	3	3	4	4	4	4	4
	–	2	2	2	1	1					
	+										
WEST	0	1	3	3	3	3	3	3	3	4	4
	–	3	1	1	1	1	1	1	1		
	+	2	2	2	1	1	2	1			
NORTH	0	2	2	2	3	2	1	2	3	3	3
	–					1	1	1	1	1	1
	+		1		1	1	1	1	1	1	1
SOUTH	0	3	2	4	3	3	3	3	3	3	3
	–	1	1								

Table 4-4: Analysis of 0 to 500 Hz data recorded during 1800 sessions in the Spring of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+										
EAST	0				1	1	1	2	2	1	2
	-	3	3	3	2	2	2	1	1	2	1
	+		1	1				1	1	1	
WEST	0	2	1	1	1	1	3	2	2	2	3
	-	1	1	1	2	2					
	+	3	2	2	2	1	1		1	1	1
NORTH	0		1	1	1	2	2	3	2	2	2
	-										
	+										
SOUTH	0	3	1	1	2	2	2	2	2	2	2
	-		2	2	1	1	1	1	1	1	1

Table 4-5: Analysis of 0 to 500 Hz data recorded during 2300 sessions in the Spring of 1981

Direction	Frequency Band	0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+	1	1	1	0	1	1	1	1	2	1
EAST	0	6	8	8	11	10	11	11	12	10	13
	-	9	7	7	5	5	4	4	3	4	2
	+	1	2	2	1	1	1	2	2	2	1
WEST	0	10	9	10	10	9	11	10	10	11	12
	-	5	5	4	5	6	4	4	4	3	3
	+	6	6	7	5	4	5	4	3	3	4
NORTH	0	9	9	8	9	9	9	9	10	10	9
	-	1	1	1	2	3	2	3	3	3	3
	+	2	2		1	1	1	1	1	1	1
SOUTH	0	12	8	10	10	10	11	11	11	11	10
	-	2	6	6	5	5	4	4	4	4	5

Table 4-6: Analysis of 0 to 500 Hz data recorded in the Spring of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+										
EAST	0	2	2	2	2	2	2	3	3	3	1
	-	1	1	1	1	1	1				2
	+										
WEST	0	3	2	3	3	3	3	3	3	3	2
	-		1								1
	+										
NORTH	0	2	1	2	2	3	3	3	3	3	3
	-	1	2	1	1						
	+	1	1	1	1	1	1	1	1		
SOUTH	0	2	2	2	2	2	2	2	2	3	2
	-										1

Table 4-7: Analysis of the 0 to 2500 Hz data recorded during 0300 sessions in the Spring of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+	1									
EAST	0	3	3	4	4	3	4	4	4	3	3
	-		1			1				1	1
	+	1	1	1	1	1	1	1	1	1	1
WEST	0	3	3	3	3	3	3	3	3	3	3
	-										
	+		1								
NORTH	0	3	2	3	3	3	2	2	2	2	2
	-	1	1	1	1	1	2	2	2	2	2
	+										
SOUTH	0	2	3	3	3	3	3	3	3	2	3
	-	2	1	1	1	1	1	1	1	2	1

Table 4-8: Analysis of the 0 to 2500 Hz data recorded during 0800 sessions in the Spring of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+										
EAST	0	1	2	2	2	2	2	1	2	1	1
	-	1						1		1	1
	+	1	1	1	1	1	1	1	1	1	1
WEST	0	1	1	1	1	1	1	1	1	1	1
	-										
	+										
NORTH	0	2	1	1	1	1	1	1	1	1	1
	-		1	1	1	1	1	1	1	1	1
	+										
SOUTH	0	2		1							
	-		2	1	2	2	2	2	2	2	2

Table 4-9: Analysis of the 0 to 2500 Hz data recorded during 1300 sessions in the Spring of 1981

Direction	Frequency Band	0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+										
EAST	0	2	2	2	2	1	2	2	2	2	2
	-					1					
	+										
WEST	0	1	1	1	2	1	2	2	2	2	2
	-	1	1	1		1					
	+										
NORTH	0	1	2	1	1	1	1	1	1	1	1
	-	1		1	1	1	1	1	1	1	1
	+		1	1	1	1	1	1			
SOUTH	0	2	1	1	1	1	1	1	1	2	2
	-								1		

Table 4-10: Analysis of the 0 to 2500 Hz data recorded during 1800 sessions in the Spring of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+										
EAST	0	3	2	3	3	3	3	3	3	2	3
	-	1	2	1	1	1	1	1	1	2	1
	+	1			1	1	1	1	1	1	2
WEST	0	1	3	4	3	3	3	3	3	3	2
	-	2	1								
	+	1	2								
NORTH	0	3	2	4	4	4	4	4	3	3	4
	-								1	1	
	+										
SOUTH	0	2	2	3	3	4	4	3	3	4	3
	-	2	2	1	1			1	1		1

Table 4-11: Analysis of the 0 to 2500 Hz data recorded during 2300 sessions in the Spring of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+	1									
EAST	0	11	11	13	13	11	13	13	14	11	10
	-	3	4	2	2	4	2	2	1	4	5
	+	3	2	2	3	3	3	3	3	3	4
WEST	0	9	10	12	12	11	12	12	12	12	10
	-	3	3	1		1					1
	+	1	3								
NORTH	0	11	8	11	11	12	11	11	10	10	11
	-	3	4	4	4	3	4	4	5	5	4
	+	1	2	2	2	2	2	2	1		
SOUTH	0	10	8	10	9	10	10	9	9	11	10
	-	4	5	3	4	3	3	4	5	4	5

Table 4-12: Analysis of the 0 to 2500 Hz data recorded in the Spring of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+										
EAST	0	3	3	4	4	3	3	3	3	3	3
	-	1	1			1	1	1	1	1	1
	+						1		1	1	1
WEST	0	4	4	4	3	2	1	2	1	1	1
	-				1	2	2	2	2	2	2
	+	2	1								
NORTH	0	2	3	4	4	4	4	4	4	4	4
	-										
	+										
SOUTH	0	2	2	3	3	3	3	3	3	3	4
	-	2	2	1	1	1	1	1	1	1	

Table 4-13: Analysis of 0 to 500 Hz data recorded during 0300 sessions in the Fall of 1981

Direction \ Frequency Band		0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500
	+	1						1	1	1	1
EAST	0	1	2	1	1	1	1				
	-			1	1	1	1	1	1	1	1
	+		1		2				1		1
WEST	0	2	1	2		2	2	2	1	2	1
	-										
	+					1	1	1	1	1	1
NORTH	0	1	1	2	2	1	1	1			
	-	1	1						1	1	1
	+										
SOUTH	0	1	1								
	-	1	1	2	2	2	2	2	2	2	2

Table 4-14: Analysis of 0 to 500 Hz data recorded during 0800 sessions in the Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+				1	1	1	1	1	1	
EAST	0	1	2	2	1	2	2	2	2	2	3
	-	3	2	2	2	1	1	1	1	1	1
	+	1	1								
WEST	0	2	2	4	3	4	4	4	4	4	4
	-	1	1		1						
	+	1	2	2	1	2	3	3	3	2	2
NORTH	0	2	1	2	3	2	1	1	1	2	2
	-	1	1								
	+										
SOUTH	0	2	3	1		1	1	1	1	1	2
	-	2	1	3	4	3	3	3	3	3	2

Table 4-15: Analysis of 0 to 500 Hz data recorded during 1300 sessions in the Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+			1	2	2	2	2	2	2	2
EAST	0	5	4	4	3	3	3	3	3	3	3
	−		1								
	+										
WEST	0	2	2	2	1	1	1	1	1	1	1
	−	3	3	3	4	4	4	4	4	4	4
	+		1								
NORTH	0	5	3	4	3	3	3	3	3	3	3
	−		1	1	2	2	2	2	2	2	2
	+			1	2	2	2	2	2	2	2
SOUTH	0	5	4	4	2	2	2	2	2	3	3
	−		1		1	1	1	1	1		

Table 4-16: Analysis of 0 to 500 Hz data recorded during 1800 sessions in the Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+	1	1	1	3	2	2	2	2	2	2
EAST	0	3	5	5	3	4	4	4	4	4	4
	-	2									
	+										
WEST	0	4	4	4	3	3	3	3	3	3	3
	-	2	2	2	3	3	3	3	3	3	3
	+	1		1	1	1	1	1	1	1	1
NORTH	0	5	5	4	4	4	5	5	5	5	5
	-		1	1	1	1					
	+	2									
SOUTH	0	3	5	3	3	4	4	4	4	4	4
	-	1	1	3	3	2	2	2	2	2	2

Table 4-17: Analysis of 0 to 500 Hz data recorded during 2300 sessions in the Fall of 1981

Direction \ Frequency Band		0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500
	+	2	1	2	6	5	5	6	6	6	5
EAST	0	13	16	16	12	13	13	12	12	12	13
	–	6	4	3	3	3	3	3	3	3	3
	+	1	2		2		1		2	1	2
WEST	0	14	13	16	10	12	11	12	10	11	10
	–	6	6	5	9	9	9	9	9	9	9
	+	4	4	3	2	4	5	5	5	4	4
NORTH	0	15	13	16	16	14	14	14	13	14	14
	–	2	4	2	3	3	2	2	3	3	3
	+	2	0	1	2	2	2	2	2	2	2
SOUTH	0	13	15	11	8	10	10	10	10	11	13
	–	6	6	9	11	9	9	9	9	8	6

Table 4-18: Analysis of 0 to 500 Hz data recorded in the Fall of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+		1	1							
EAST	0	3	2	2	4	4	4	4	4	4	3
	-	1	1	1							1
	+										
WEST	0	4	3	3	4	3	3	3	2	2	3
	-		1	1		1	1	1	2	2	1
	+	1	1	1	2	2	2	2	3	3	3
NORTH	0	3	3	3	2	2	2	2	1	1	1
	-										
	+										
SOUTH	0	2	2	3	2	1	1	1	1		
	-	2	2	1	2	3	3	3	3	4	4

Table 4-19: Analysis of 0 to 2500 Hz data recorded during 0300 sessions in the Fall of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+							1	1	1	1
EAST	0	2	1	2	2	2	1	1	1	1	1
	-	1	2	1	1	1	2	1	1	1	1
	+	1	1	1	1	1	1	1	2	1	1
WEST	0	2	1	1	1	1	1	1		1	1
	-		1	1	1	1	1	1	1	1	1
	+	1	2	2	2	2	2	2	2	2	2
NORTH	0	1									
	-	1	1	1	1	1	1	1	1	1	1
	+										
SOUTH	0	1									
	-	2	3	3	3	3	3	3	3	3	3

Table 4-20: Analysis of 0 to 2500 Hz data recorded during 0800 sessions in the Fall of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+		1								
EAST	0	3	2	3						1	1
	-	1	1	1	4	4	4	4	4	3	3
	+				2	2	2	1			
WEST	0	3	2	3	1	1	1	2	3	3	3
	-	1	2	1	1	1	1	1	1	1	1
	+	3	1	3	3	3	3	2	3	4	4
NORTH	0	1	3	1	1	1	1	2	1		
	-										
	+										
SOUTH	0		2								1
	-	4	2	4	4	4	4	4	4	4	3

Talbe 4-21: Analysis of 0 to 2500 Hz data recorded during 1300 sessions in the Fall of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+	1	2								
EAST	0	4	3	5	5	4	4	4	4	2	2
	–					1	1	1	1	3	3
	+				1	1	1	1	1	1	1
WEST	0	2	1	2	3	3	3	3	3	3	2
	–	3	4	3	1	1	1	1	1	1	2
	+	1		1	1	2	1	2	4	4	4
NORTH	0	2	3	4	4	3	4	3	1	1	1
	–	2	2								
	+		1	1							
SOUTH	0	5	4	4	4	3	3	3	2		
	–				1	2	2	2	3	5	5

Table 4-22: Analysis of 0 to 2500 Hz data recorded during 1800 sessions in the Fall of 1981

Direction	Frequency Band	0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
EAST	+	1	2	2							1
	0	4	4	4	5	5	5	5	4	3	2
	-	1			1	1	1	1	2	3	3
WEST	+										
	0	3	3	3	3	5	5	5	5	5	5
	-	3	3	3	3	1	1	1	1	1	1
NORTH	+	1	1		1	1	2	2	2	3	4
	0	5	5	6	5	5	4	4	4	3	2
	-										
SOUTH	+										
	0	4	4	4	5	5	5	5	5	3	2
	-	2	2	2	1	1	1	1	1	3	4

Table 4-23: Analysis of 0 to 2500 Hz data recorded during 2300 sessions in the Fall of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+	2	6	3			0	1	1	1	2
EAST	0	16	12	16	16	15	14	14	13	11	9
	-	4	4	3	6	7	8	7	8	10	11
	+	1	1	1	4	4	4	3	3	2	2
WEST	0	14	10	12	12	13	13	14	13	14	14
	-	7	11	9	6	5	5	5	6	6	6
	+	7	5	7	9	10	10	10	14	16	17
NORTH	0	12	14	14	12	11	11	11	7	5	4
	-	3	3	1	1	1	1	1	1	1	1
	+		1	1							
SOUTH	0	12	12	11	11	9	9	9	8	3	3
	-	10	9	10	11	13	13	13	14	19	19

Table 4-24: Analysis of 0 to 2500 Hz data recorded in the Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+	1	1	1							
EAST	0	3	3	5	6	5	5	5	6	6	6
	-	3	3	1	1	2	2	2	1	1	1
	+	1	1	1	1	1	2	1	2	2	2
WEST	0	6	6	6	5	4	3	4	3	3	3
	-				1	2	2	2	2	2	2
	+	2	2								
NORTH	0	4	4	6	6	6	6	6	6	6	6
	-	1	1	1	1	1	1	1	1	1	1
	+										
SOUTH	0	4	4	5	5	5	5	5	5	5	6
	-	3	3	2	2	2	2	2	2	2	1

Table 4-25: Analysis of 0 to 500 Hz data recorded during 0300 sessions in the Spring and Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+	1					1	2	2	2	2
EAST	0	3	6	4	4	4	3	1	1	1	2
	-	2		2	2	2	2	3	3	3	2
	+		1		2				1		1
WEST	0	5	3	4	3	4	4	4	3	4	3
	-	1	2	2	1	2	2	2	2	2	2
	+		1	2	1	2	2	3	2	2	3
NORTH	0	5	4	4	5	4	4	2	2	2	1
	-	1	1					1	2	2	2
	+	2	1								
SOUTH	0	3	3	3	3	3	4	4	4	4	3
	-	1	2	3	3	3	2	2	2	2	3

Table 4-26: Analysis of 0 to 500 Hz data recorded during 0800 sessions in the Spring and Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+				1	2	1	1	1	2	
EAST	0	3	4	4	3	3	4	4	4	3	5
	-	3	2	2	2	1	1	1	1	1	1
	+	1	1								
WEST	0	4	3	6	4	5	5	5	5	5	5
	-	1	2		2	1	1	1	1	1	1
	+	2	2	3	2	3	4	4	4	3	3
NORTH	0	3	3	3	3	2	2	2	2	3	3
	-	1	1		1	1					
	+										
SOUTH	0	4	4	1		1	1	1	1	1	2
	-	2	2	5	6	5	5	5	5	5	4

Table 4-27: Analysis of 0 to 500 Hz data recorded during 1300 sessions in the Spring and Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+			1	2	2	2	2	2	2	2
EAST	0	7	6	6	6	6	7	7	7	7	7
	-	2	3	2	1	1					
	+										
WEST	0	3	5	5	4	4	4	4	4	5	5
	-	6	4	4	5	5	5	5	5	4	4
	+	2	3	2	1	1	2	1			
NORTH	0	7	5	6	6	5	4	5	6	6	6
	-		1	1	2	3	3	3	3	3	3
	+		1	1	3	3	3	3	3	3	3
SOUTH	0	8	6	8	5	5	5	5	5	6	6
	-	1	2		1	1	1	1	1		

Table 4-28: Analysis of 0 to 500 Hz data recorded during 1800 sessions in the Spring and Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
	+	1	1	1	3	2	2	2	2	2	2
EAST	0	3	5	5	4	5	5	6	6	5	6
	-	5	3	3	2	2	2	1	1	2	1
	+		1	1				1	1	1	
WEST	0	6	5	5	4	4	6	5	5	5	6
	-	3	3	3	5	5	3	3	3	3	3
	+	4	2	3	3	2	2	1	2	2	2
NORTH	0	5	6	5	5	6	7	8	7	7	7
	-		1	1	1	1					
	+	2									
SOUTH	0	6	6	4	5	6	6	6	6	6	6
	-	1	3	5	4	3	3	3	3	3	3

Table 4-29: Analysis of 0 to 500 Hz data recorded during 2300 sessicns in the Spring and Fall of 1981

Direction	Frequency Band	0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+		1	1							
EAST	0	5	4	4	6	6	6	7	7	7	4
	-	2	2	2	1	1	1				3
	+										
WEST	0	7	5	6	7	6	6	6	5	5	5
	-		2	1		1	1	1	2	2	2
	+	1	1	1	2	2	2	2	3	3	3
NORTH	0	5	4	5	4	5	5	5	4	4	4
	-	1	2	1	1						
	+	1	1	1	1	1	1	1	1		
SOUTH	0	4	4	5	4	3	3	3	3	3	2
	-	2	2	1	2	3	3	3	3	4	5

Table 4-30: Analysis of 0 to 2500 Hz data recorded during 0300 sessions in the Spring and Fall of 1981

Direction	Frequency Band	0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+	1						1	1	1	1
EAST	0	5	4	6	6	5	5	5	5	4	4
	-	1	3	1	1	2	2	1	1	2	2
	+	2	2	2	2	2	2	2	3	2	2
WEST	0	5	4	4	4	4	4	4	3	4	4
	-		1	1	1	1	1	1	1	1	1
	+	1	3	2	2	2	2	2	2	2	2
NORTH	0	4	2	3	3	3	2	2	2	2	2
	-	2	2	2	2	2	3	3	3	3	3
	+										
SOUTH	0	3	3	3	3	3	3	3	3	2	3
	-	4	4	4	4	4	4	4	4	5	4

Table 4-31: Analysis of 0 to 2500 Hz data recorded during 0800 sessions in the Spring and Fall of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+		1								
EAST	0	4	4	5	2	2	2	1	2	2	2
	-	2	1	1	4	4	4	5	4	4	4
	+	1	1	1	3	3	3	2	1	1	1
WEST	0	4	3	4	2	2	2	3	4	4	4
	-	1	2	1	1	1	1	1	1	1	1
	+	3	1	3	3	3	3	2	3	4	4
NORTH	0	3	4	2	2	2	2	3	2		
	-		1	1	1	1	1	1	1	1	1
	+										
SOUTH	0	2	2	1							1
	-	4	4	5	6	6	6	6	6	6	5

Table 4-32: Analysis of 0 to 2500 Hz data recorded during 1300 sessions in the Spring and Fall of 1981

AD-A120 450 MEASUREMENTS OF THE HORIZONTAL DIRECTIONALITY OF THE AMBIENT ACOUSTIC NOISE IN MONTEREY BAY CALIFORNIA(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA M J GAGLIARDI MAR 82 F/G 20/1

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+	1	2								
EAST	0	4	5	7	7	5	6	6	6	4	4
	-					2	1	1	1	3	3
	+				1	1	1	1	1	1	1
WEST	0	3	2	3	5	4	5	5	5	5	4
	-	4	5	4	1	2	1	1	1	1	2
	+	1		1	1	2	1	2	4	4	4
NORTH	0	3	5	5	5	4	5	4	2	2	2
	-	3	2	1	1	1	1	1	1	1	1
	+		2	2	1	1	1	1			
SOUTH	0	7	5	5	5	4	4	4	3	2	2
	-				1	2	2	2	4	5	5

Table 4-33: Analysis of 0 to 2500 Hz data recorded during 1800 sessions in the Spring and Fall of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+	1	2	2							1
EAST	0	7	6	7	8	8	8	8	7	5	5
	-	2	2	1	2	2	2	2	3	5	4
	+	1			1	1	1	1	1	1	2
WEST	0	4	6	7	6	8	8	8	8	8	7
	-	5	4	3	3	1	1	1	1	1	1
	+	2	3		1	1	2	2	2	3	4
NORTH	0	8	7	10	9	9	8	8	7	6	6
	-								1	1	
	+										
SOUTH	0	6	6	7	8	9	9	8	8	7	5
	-	4	4	3	2	1	1	2	2	3	5

Table 4-34: Analysis of 0 to 2500 Hz data recorded during 2300 sessions in the Spring and Fall of 1981

Direction	Frequency Band	0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500
	+	3	6	3				1	1	1	2
EAST	0	27	23	29	29	26	27	27	27	22	19
	-	7	8	5	8	11	10	9	9	14	16
	+	4	3	3	7	7	7	6	6	5	6
WEST	0	23	20	24	24	24	25	26	25	26	24
	-	10	14	10	6	6	5	5	6	6	7
	+	8	8	7	9	10	10	10	14	16	17
NORTH	0	23	22	25	23	23	22	22	17	15	15
	-	6	7	5	5	4	5	5	6	6	5
	+	1	3	3	2	2	2	2	1		
SOUTH	0	22	20	21	20	19	19	18	17	14	13
	-	14	14	13	15	16	16	17	19	23	24

Table 4-35: Analysis of 0 to 2500 Hz data recorded in the Spring and Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500
EAST	+	3	2	3	6	6	6	7	7	8	6
	0	19	24	24	23	23	24	23	24	22	26
	-	15	11	10	8	8	7	7	6	7	5
WEST	+	2	4	2	3	1	2	2	4	3	3
	0	24	22	26	20	21	22	22	20	22	22
	-	11	11	9	14	15	13	13	13	12	12
NORTH	+	10	10	10	7	8	10	9	8	7	8
	0	24	22	24	25	23	23	23	23	24	23
	-	3	5	3	5	6	4	5	6	6	6
SOUTH	+	4	2	1	3	3	3	3	3	3	3
	0	25	23	21	18	20	21	21	21	22	23
	-	8	12	15	16	14	13	13	13	12	11

Table 4-36: Analysis of 0 to 500 Hz data recorded in the Spring and Fall of 1981

Direction \ Frequency Band		0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450	450 500	
EAST	+	4	1	2	3	1	2	2	3	2	2	
MINUS	0	11	12	12	12	13	14	13	11	11	12	4-37
WEST	-	5	7	6	5	6	4	5	6	7	6	
EAST	+	6	7	8	13	12	13	11	12	12	11	
MINUS	0	18	13	13	6	8	8	10	9	9	10	4-38
WEST	-	2	6	5	7	6	5	5	5	5	5	
EAST	+	10	8	10	16	13	15	13	15	14	13	
MINUS	0	29	25	25	18	21	22	23	20	20	22	4-39
WEST	-	7	13	11	12	12	9	10	11	12	11	

Table 4-37: Analysis of the East minus West bin levels for the 0 to 500 Hz range for data recorded in the Spring of 1981

Table 4-38: Analysis of the East minus West bin levels for the 0 to 500 Hz range for data recorded in the Fall of 1981

Table 4-39: Analysis of the East minus West bin levels for the 0 to 500 Hz range for data recorded in the Spring and Fall of 1981

Direction \ Frequency Band		0 250	250 500	500 750	750 1000	1000 1250	1250 1500	1500 1750	1750 2000	2000 2250	2250 2500	
EAST	+	1	2	2	1	1	0	1	1	3	2	
MINUS	0	10	8	10	10	9	10	11	11	7	9	4-40
WEST	-	5	6	4	5	6	6	4	4	6	5	
EAST	+	8	11	11	5	3	3	3	4	2	3	
MINUS	0	14	10	12	14	18	18	17	13	16	14	4-41
WEST	-	5	6	4	8	6	6	7	10	9	10	
EAST	+	9	13	13	6	4	3	4	5	5	5	
MINUS	0	24	18	22	24	27	28	28	24	23	23	4-42
WEST	-	10	12	8	13	12	12	11	14	15	15	

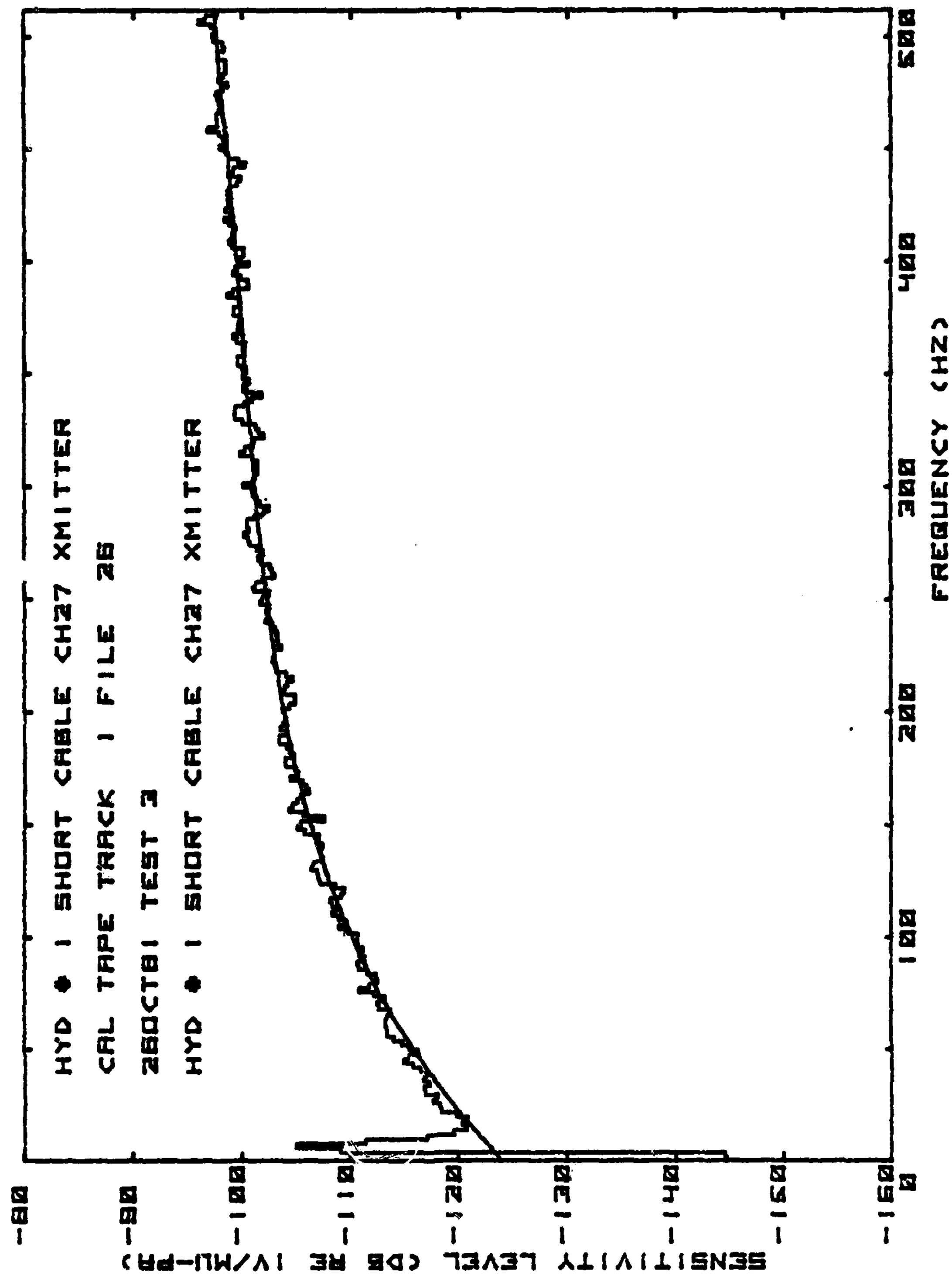
Table 4-40: Analysis of the East minus West bin levels for the 0 to 2500 Hz range for data recorded in the Spring of 1981

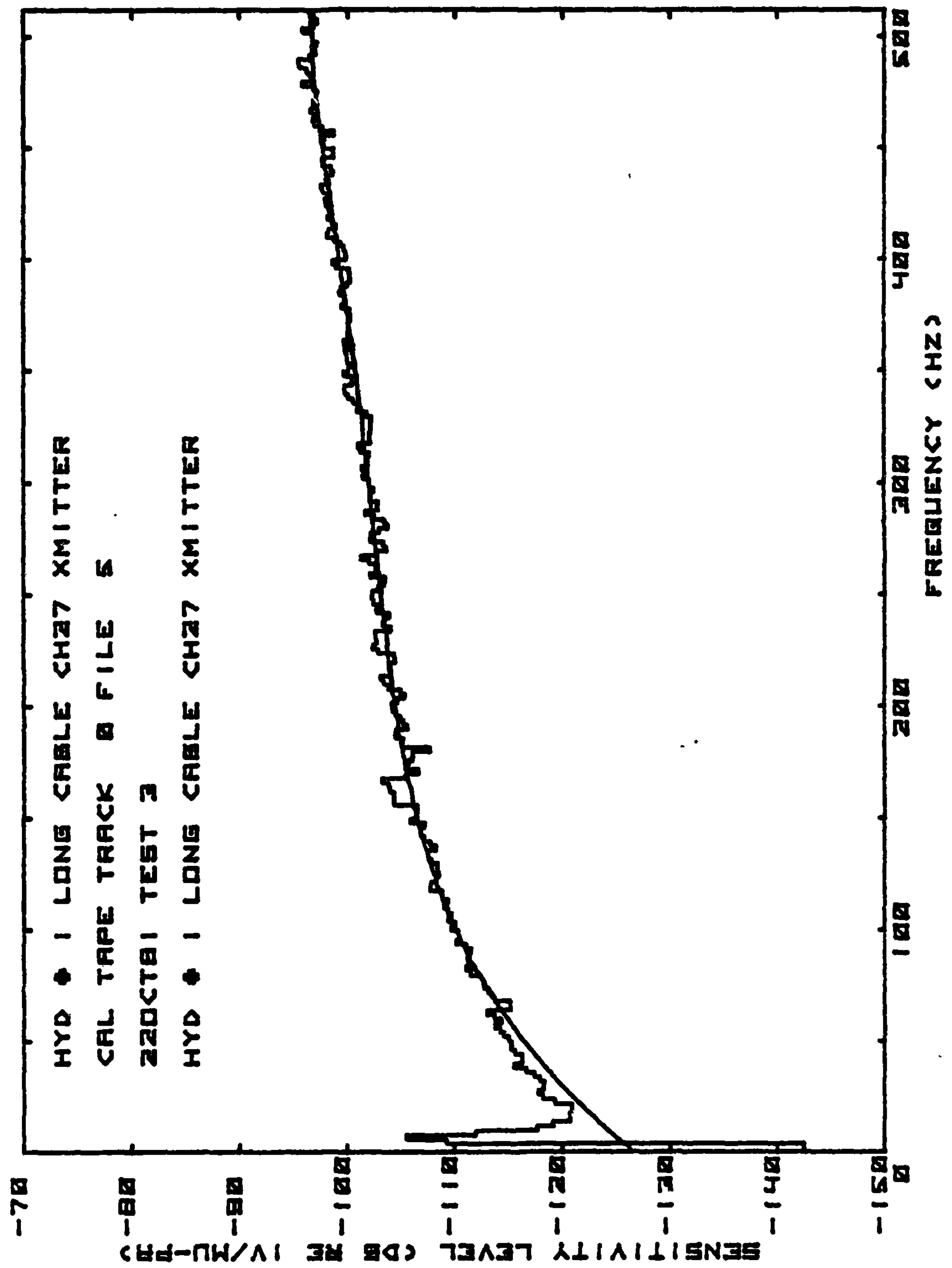
Table 4-41: Analysis of the East minus West bin levels for the 0 to 2500 Hz range for data recorded in the Fall of 1981

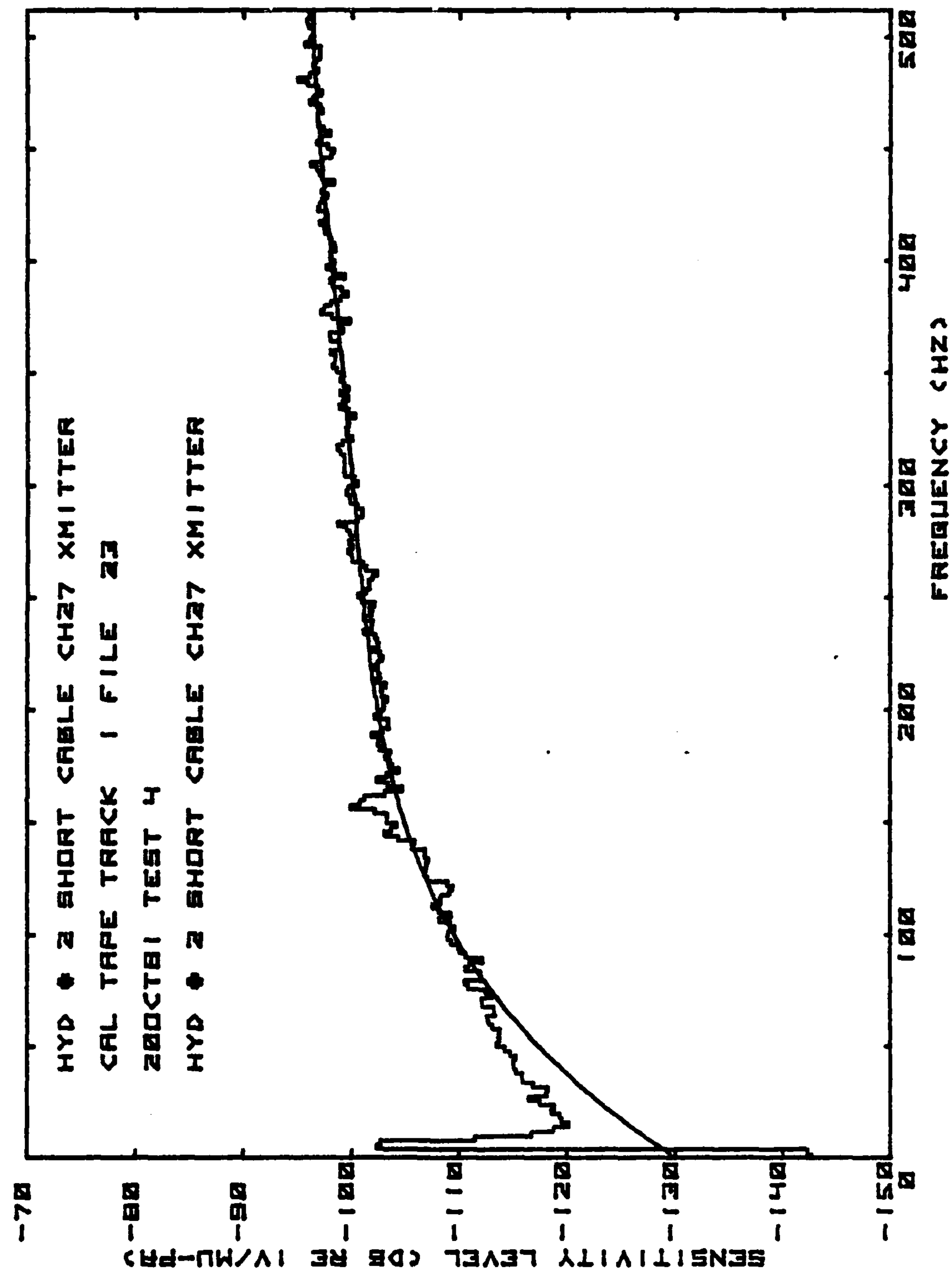
Table 4-42: Analysis of the East minus West bin levels for the 2500 Hz range for data recorded in the Spring and Fall of 1981

APPENDIX A

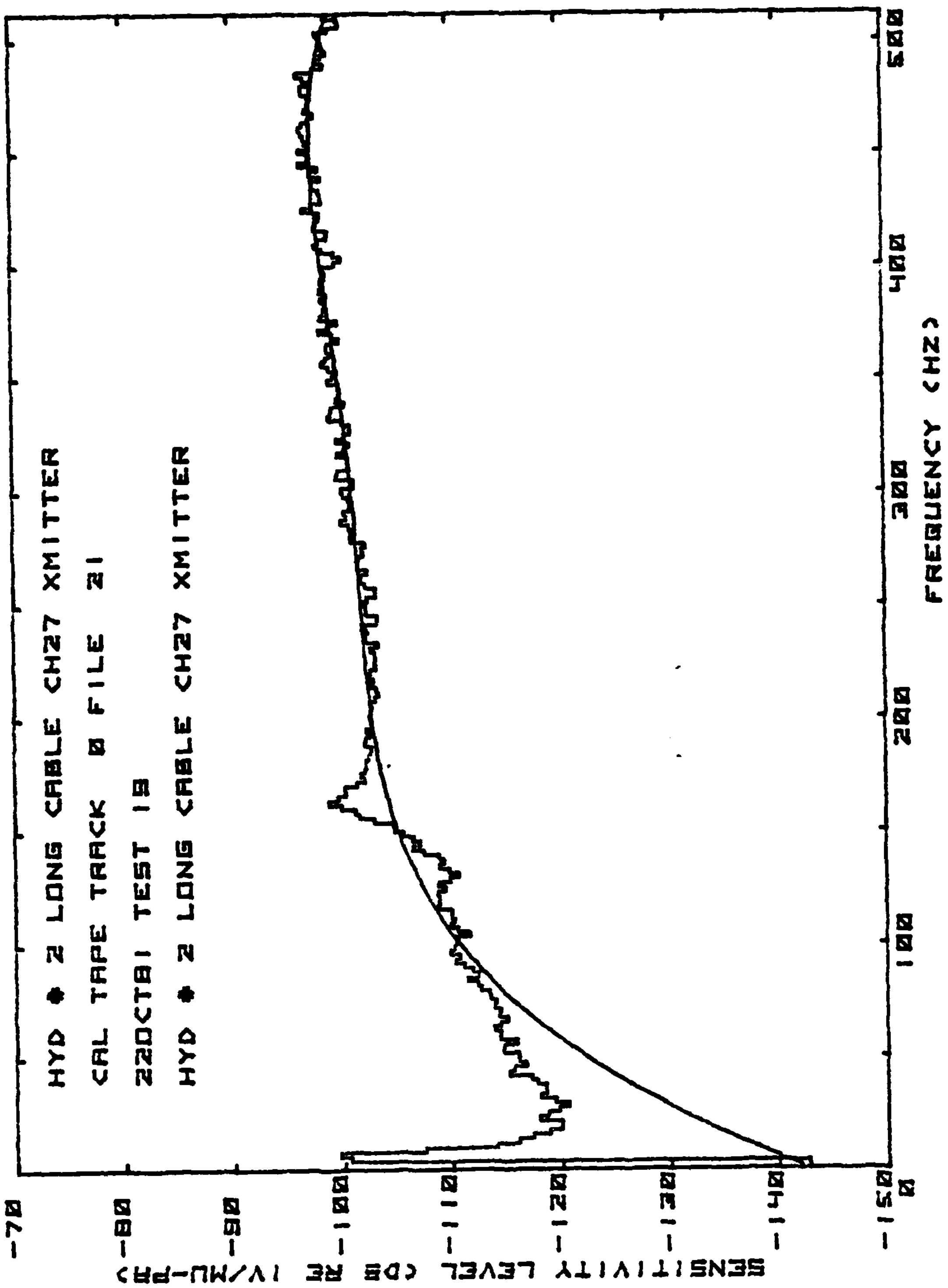
TYPICAL SENSITIVITY CURVES

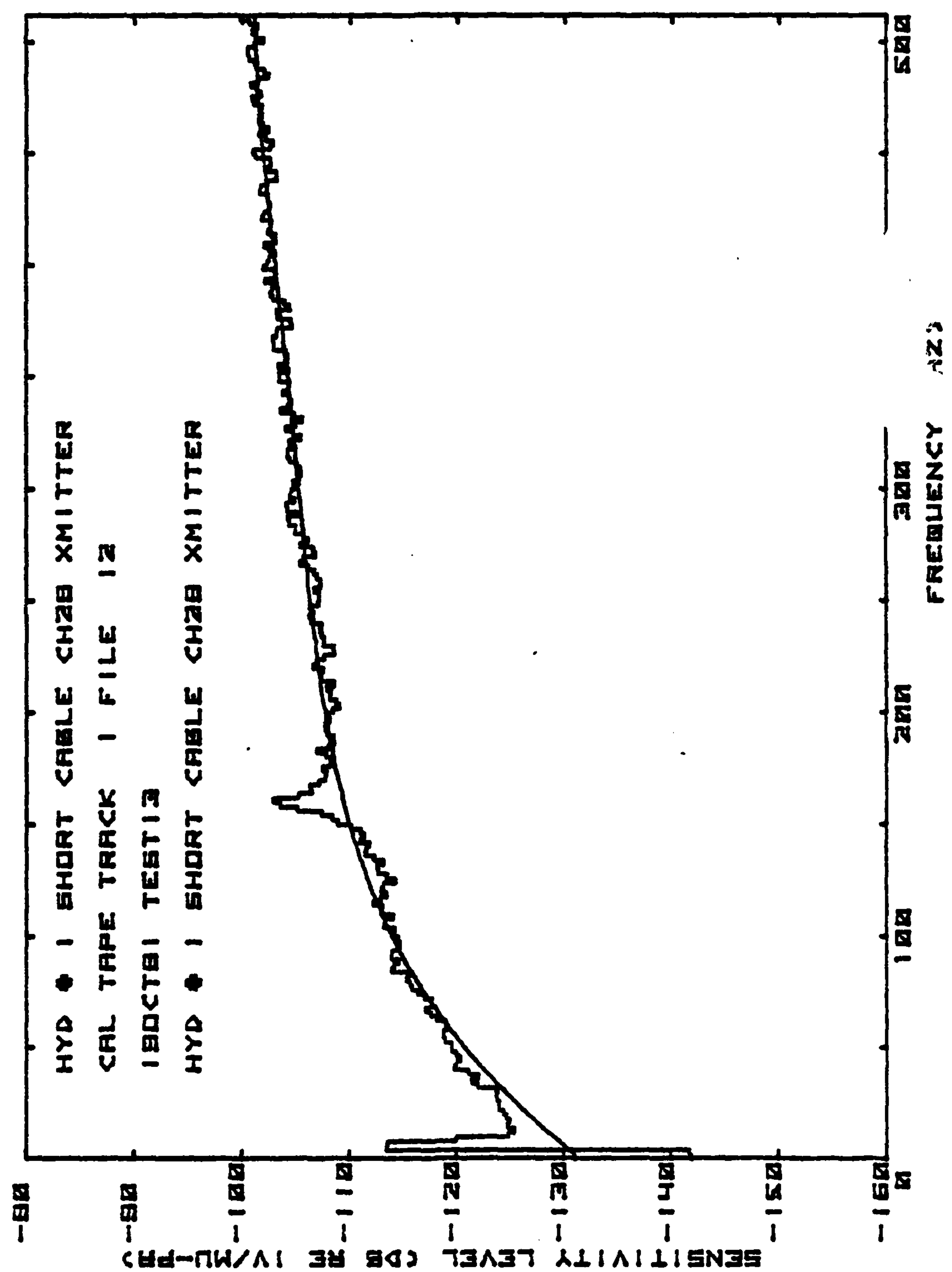


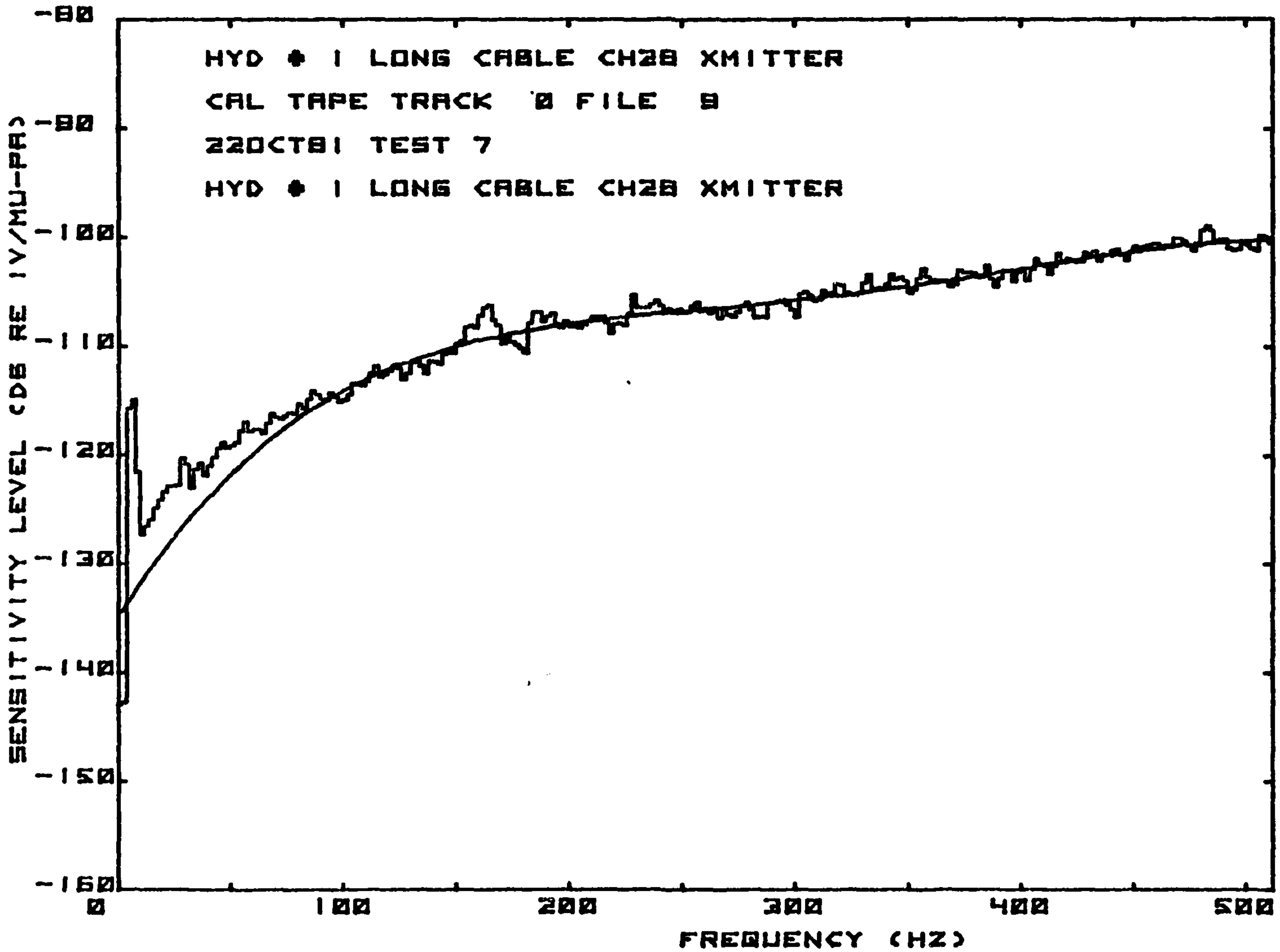

HYD # 1 LONG CABLE CH27 XMITTER
CAL TAPE TRACK 8 FILE 6
22OCT81 TEST 3
HYD # 1 LONG CABLE CH27 XMITTER
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
FREQUENCY (HZ)
-70
-80
-90
-100
-110
-120
-130
-140
-150
0
100
200
300
400
500

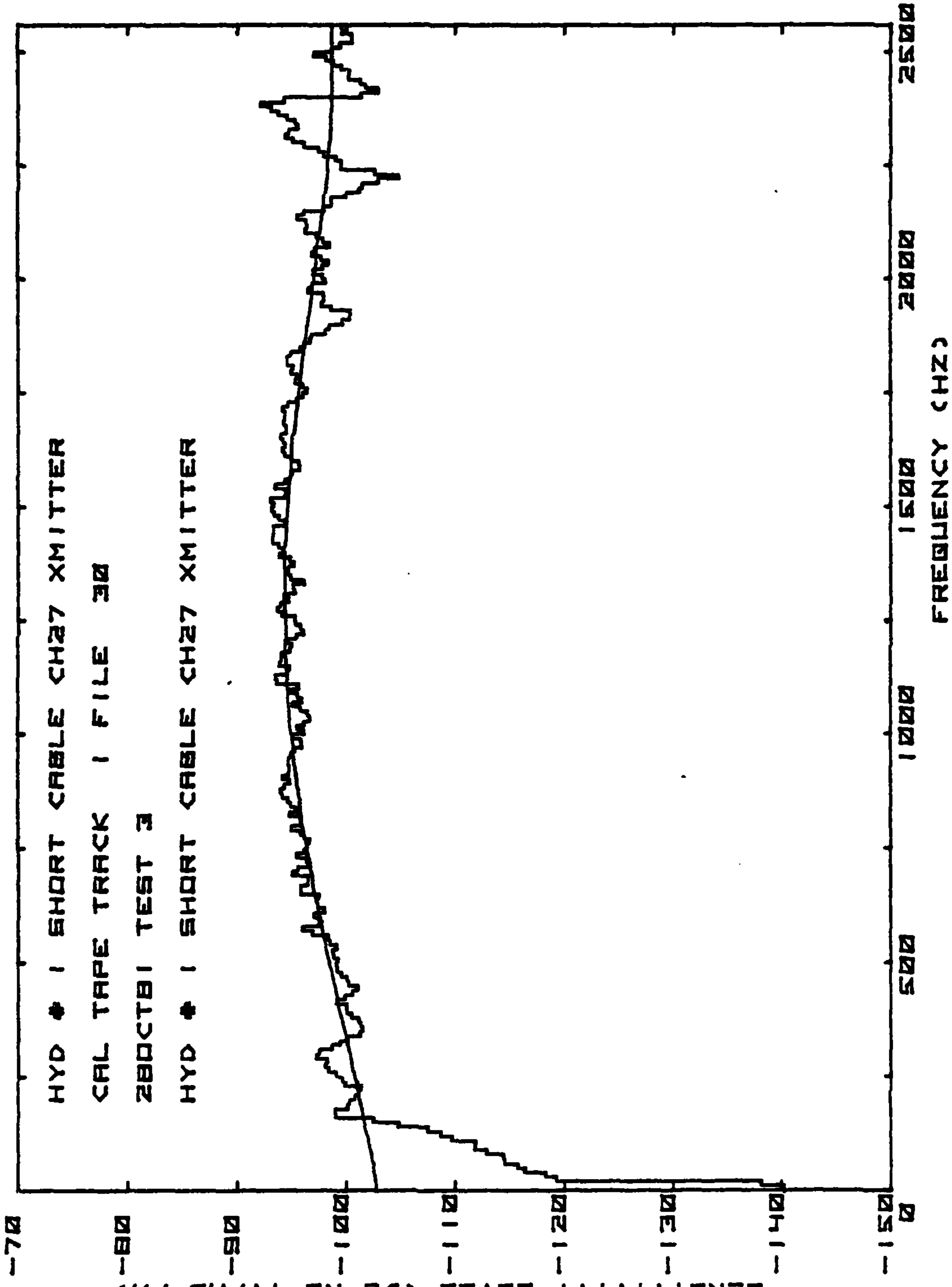


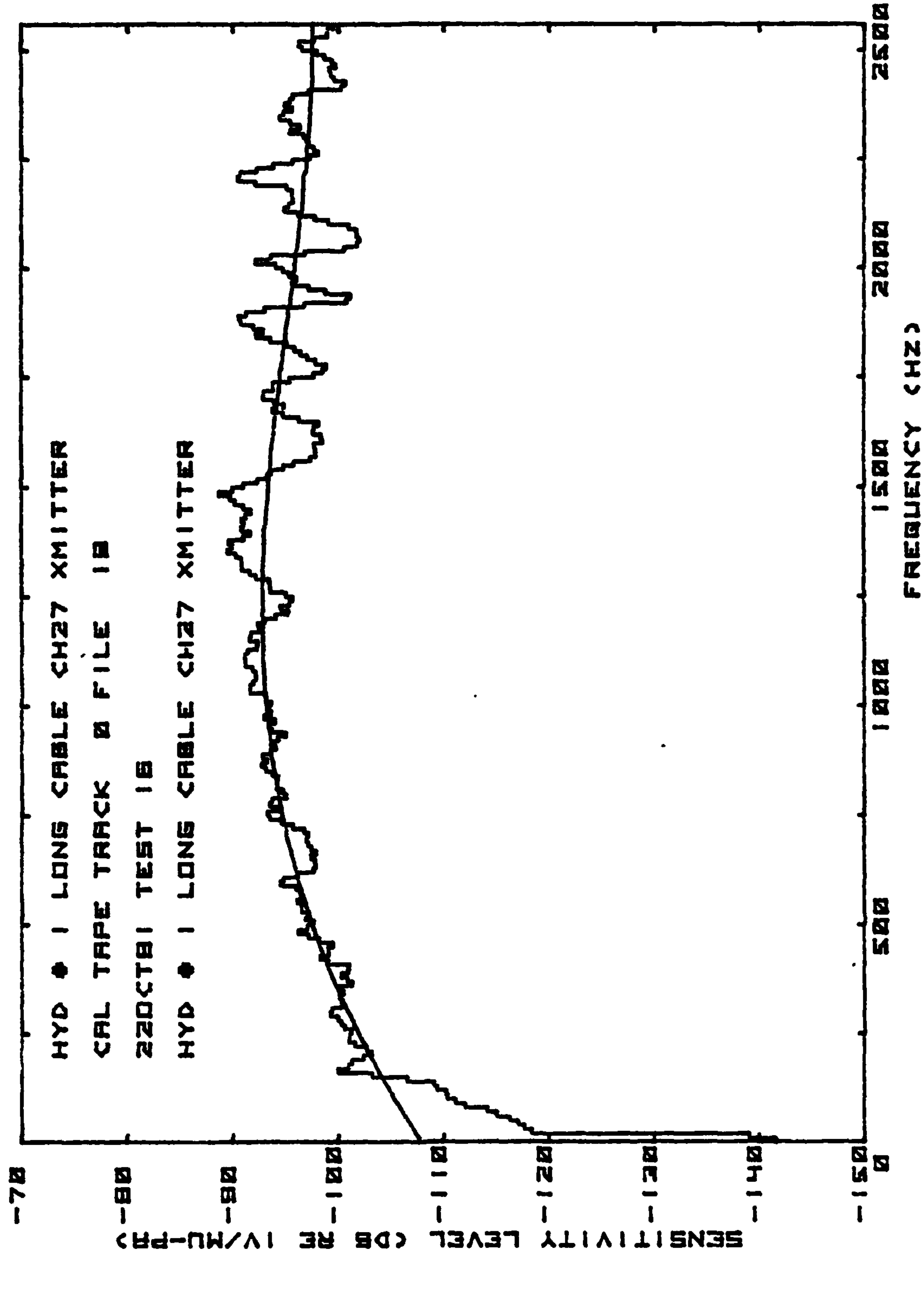
HYD # 2 SHORT CABLE CH27 XMITTER
CAL TAPE TRACK 1 FILE 23
28OCT81 TEST 4
HYD # 2 SHORT CABLE CH27 XMITTER
FREQUENCY (HZ)
0
100
200
300
400
500
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
-70
-80
-90
-100
-110
-120
-130
-140
-150

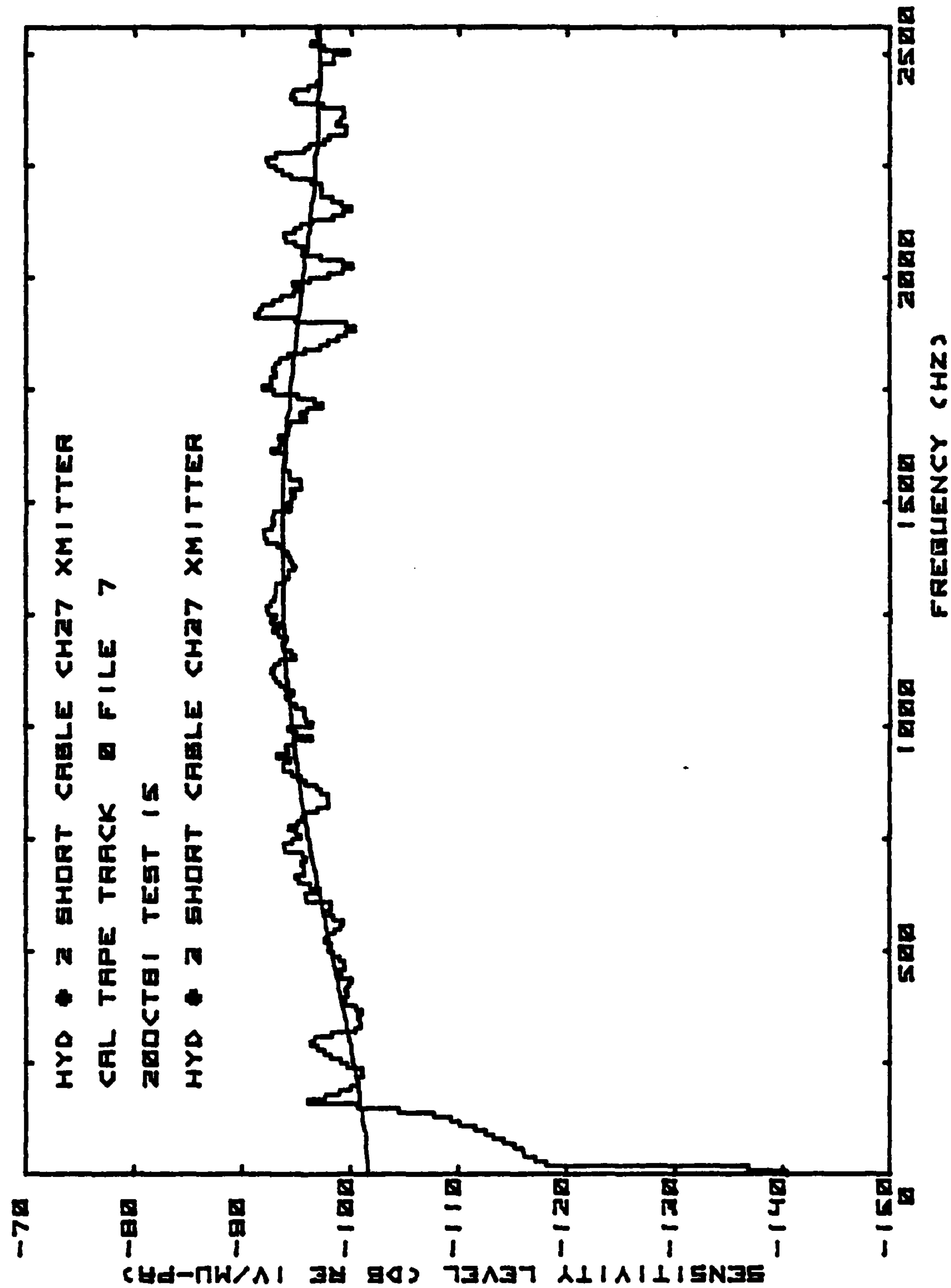

HYD # 2 LONG CABLE CH27 XMITTER
CAL TAPE TRACK 0 FILE 21
22OCT81 TEST 19
HYD # 2 LONG CABLE CH27 XMITTER
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
-70
-80
-90
-100
-110
-120
-130
-140
-150
FREQUENCY (HZ)
0
100
200
300
400
500

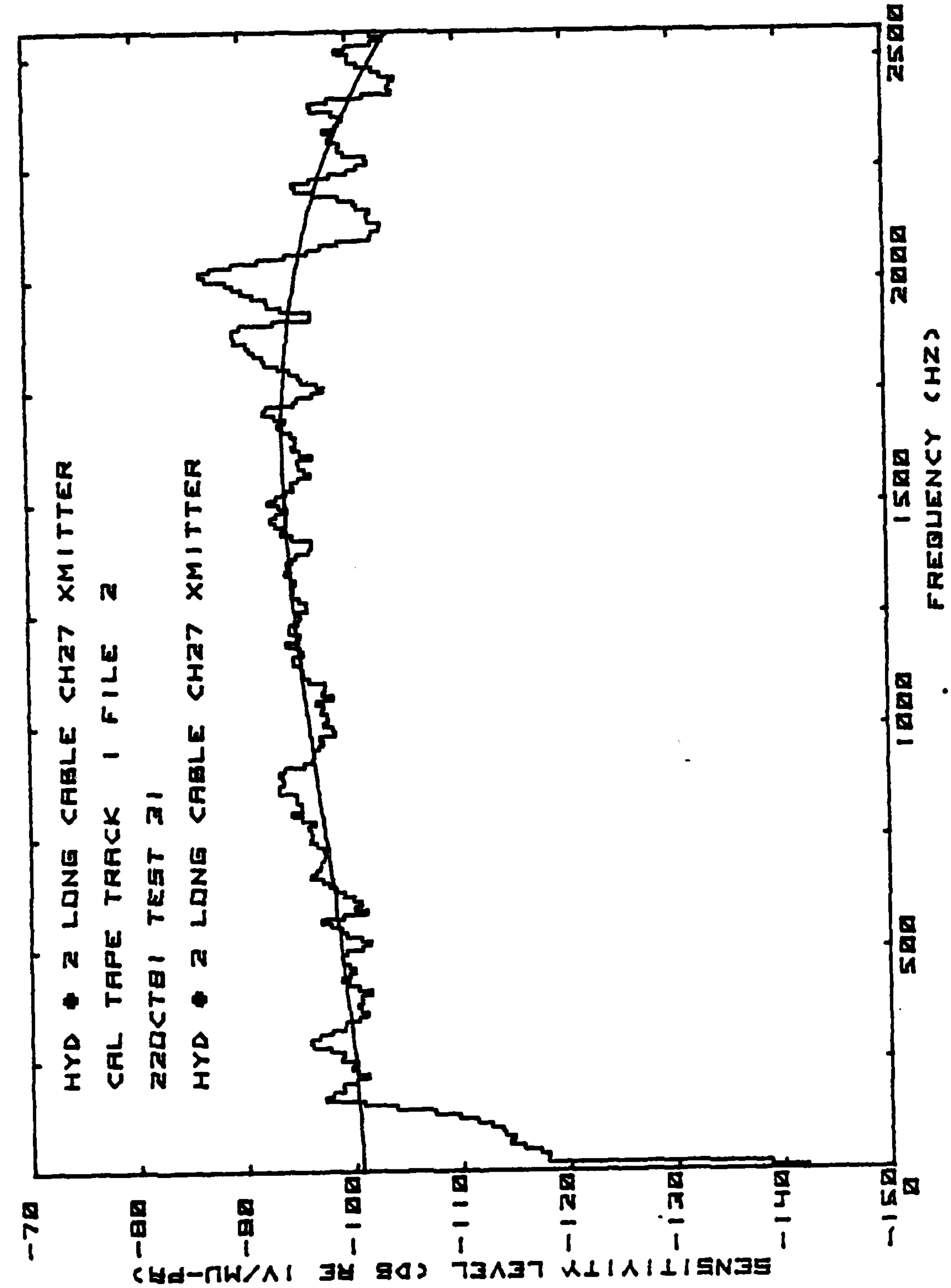

HYD # 1 SHORT CABLE CH28 XMITTER
CAL TAPE TRACK 1 FILE 12
19OCT81 TEST13
HYD # 1 SHORT CABLE CH28 XMITTER
-80
-90
-100
-110
-120
-130
-140
-150
-160
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
0
100
200
300
500
FREQUENCY (HZ)

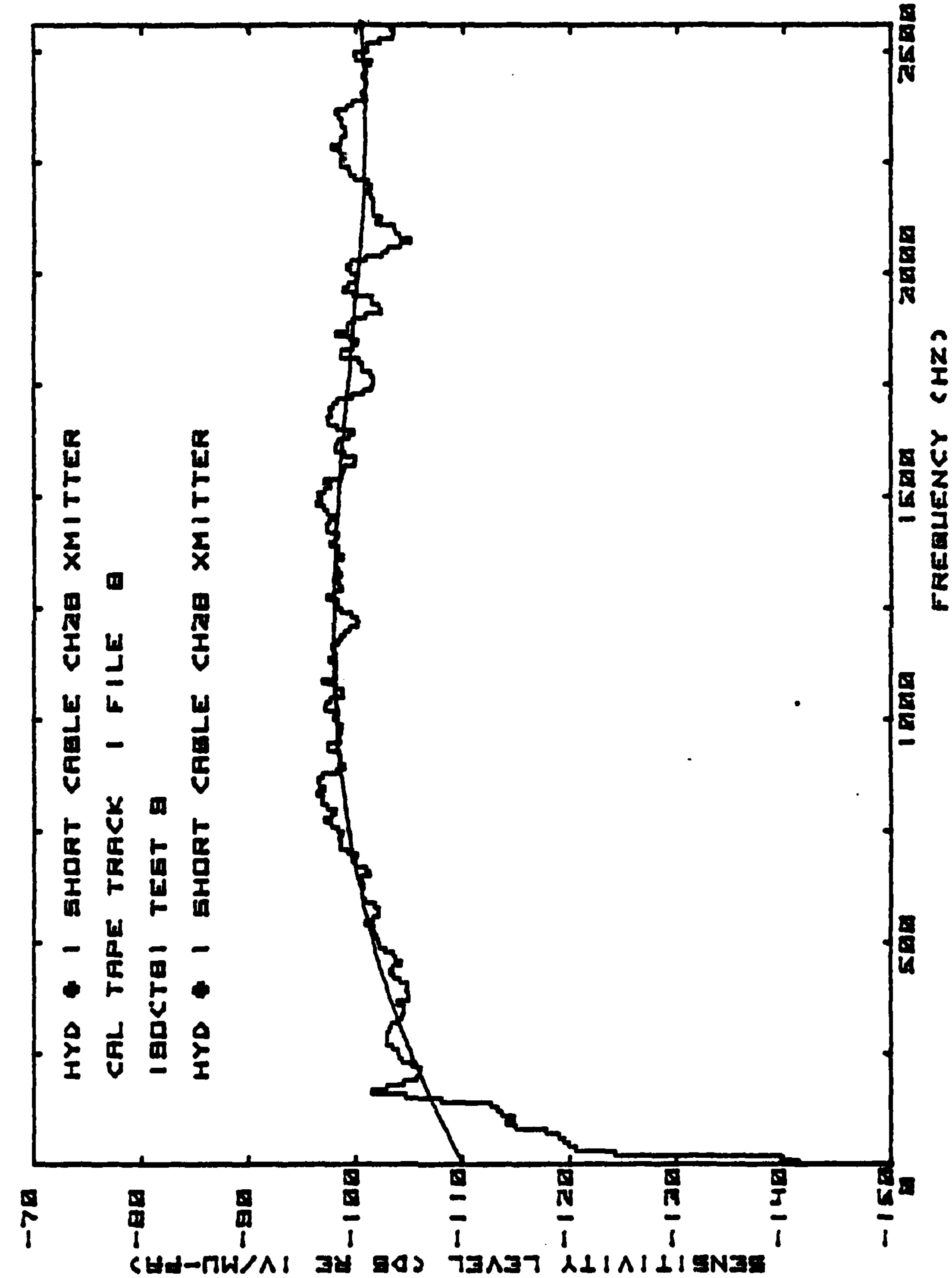

HYD # 1 LONG CABLE CH28 XMITTER
CAL TAPE TRACK 0 FILE 9
22OCT81 TEST 7
HYD # 1 LONG CABLE CH28 XMITTER
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
-80
-90
-100
-110
-120
-130
-140
-150
-160
0
100
200
300
400
500
FREQUENCY (HZ)

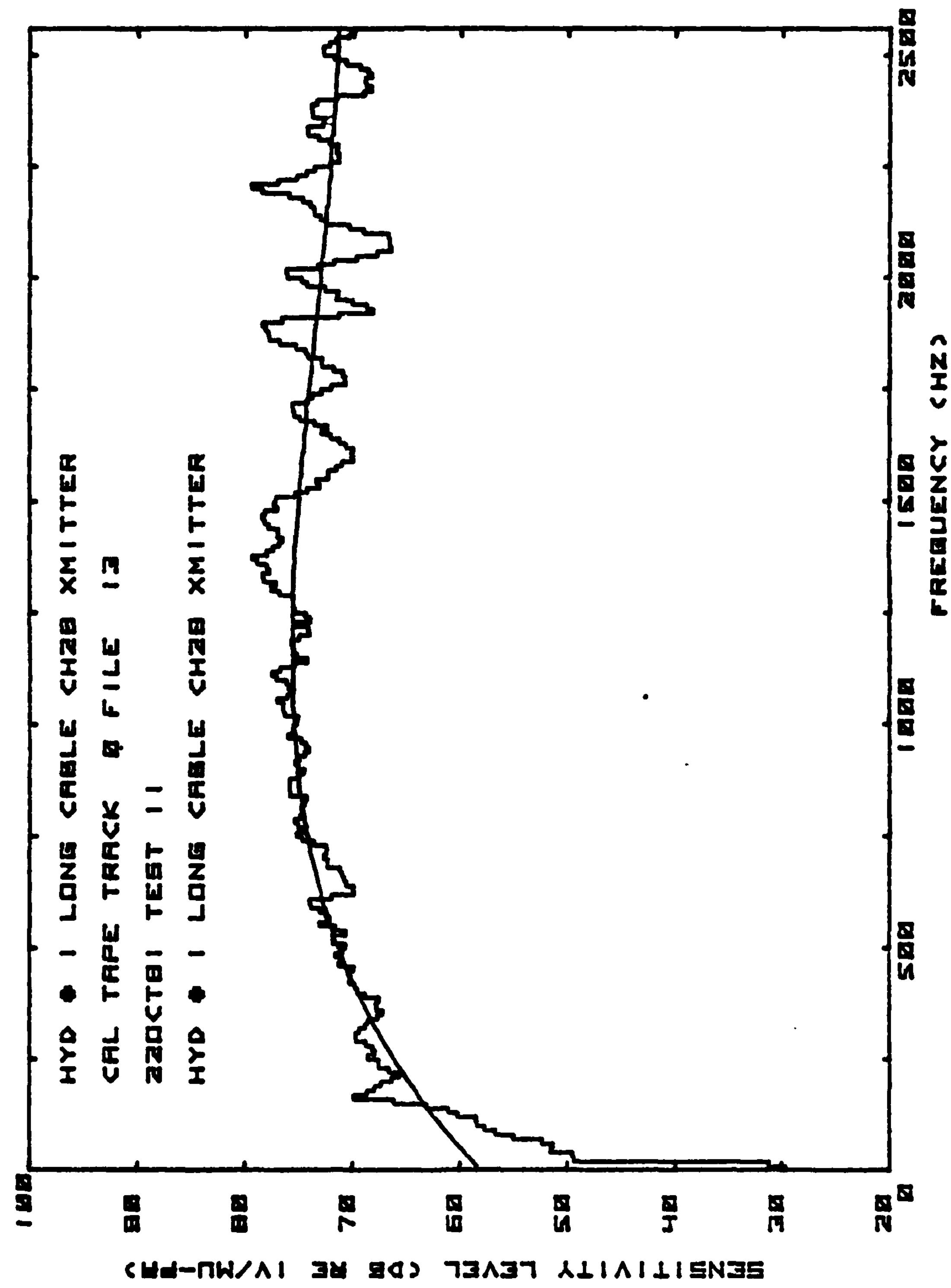

HYD # 1 SHORT CABLE CH27 XMITTER
CAL TAPE TRACK 1 FILE 30
28OCT81 TEST 3
HYD # 1 SHORT CABLE CH27 XMITTER
FREQUENCY (HZ)
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
0
500
1000
1500
2000
2500
-70
-80
-90
-100
-110
-120
-130
-140
-150


HYD # 1 LONG CABLE CH27 XMITTER
CAL TAPE TRACK 0 FILE 18
22OCT81 TEST 16
HYD # 1 LONG CABLE CH27 XMITTER
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
-70
-80
-90
-100
-110
-120
-130
-140
-150
0
500
1000
1500
2000
2500
FREQUENCY (HZ)


HYD # 2 SHORT CABLE CH27 XMITTER
CAL TAPE TRACK 0 FILE 7
20OCT81 TEST 15
HYD # 2 SHORT CABLE CH27 XMITTER
FREQUENCY (HZ)
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
0
500
1000
1500
2000
2500
-70
-80
-90
-100
-110
-120
-130
-140
-150


HYD # 2 LONG CABLE CH27 XMITTER
CAL TAPE TRACK 1 FILE 2
22OCT81 TEST 31
HYD # 2 LONG CABLE CH27 XMITTER
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
-70
-80
-90
-100
-110
-120
-130
-140
-150
FREQUENCY (HZ)
0
500
1000
1500
2000
2500


HYD # 1 SHORT CABLE CH28 XMITTER
CAL TAPE TRACK 1 FILE 8
18OCT81 TEST 8
HYD # 1 SHORT CABLE CH28 XMITTER
FREQUENCY (HZ)
0
500
1000
1500
2000
2500
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
-70
-80
-90
-100
-110
-120
-130
-140
-150


HYD # 1 LONG CABLE CH28 XMITTER
CAL TAPE TRACK 0 FILE 13
22OCT81 TEST 11
HYD # 1 LONG CABLE CH28 XMITTER
FREQUENCY (HZ)
SENSITIVITY LEVEL (DB RE 1V/MU-PA)
0
500
1000
1500
2000
2500
20
30
40
50
60
70
80
90
100

LIST OF REFERENCES

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2. Bobber, R. J., Underwater Electroacoustic Measurements, Naval Research Laboratory, 1980.

3. Bascom, W., Waves and Beaches, Anchor, 1964.

4. Wilson, O.B. and Wolf, Stephen N., Measurement of Horizontal Anisotropy of Shallow Water Ambient Noise due to Breaking Surf, Pager EE9, read at Fall, 1981, meeting of the Acoustical Society of America.

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